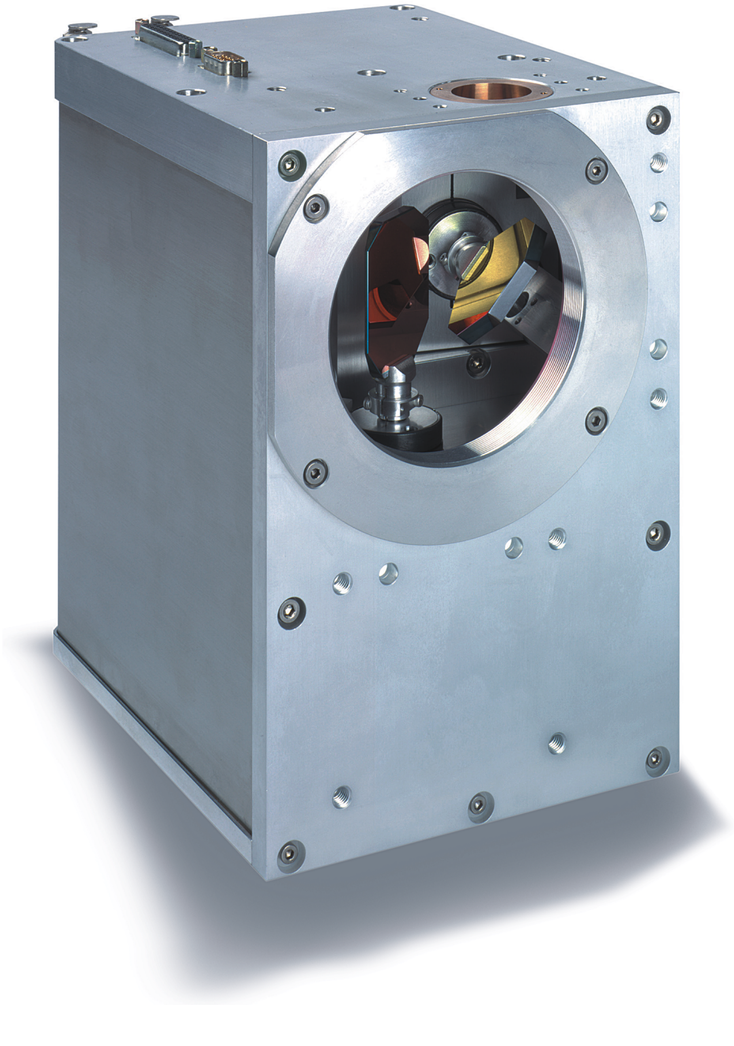
Installation and Operation

intelli*SCAN* 20 (ID# 148850)

digital SL2-100, 1064 nm, with Air- and Water-Cooling



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1 Introduction

This operating manual describes the intelli*SCAN* 20 scan head with ID number 148850.

The manual is a part of the product. Please read these instructions carefully before you proceed with installing and operating the scan head. In particular observe all safety guidelines in this manual. If there are any questions regarding the contents of this manual, please contact SCANLAB (see page 42).

Keep the manual available for servicing, repairs and product disposal. This manual should accompany the product if ownership changes hands.

SCANLAB reserves the right to update this operating manual at any time and without notification.

1.1 Product Overview

The intelli*SCAN* 20 scan head with ID number 148850 is designed for positioning laser beams with a wavelength of 1064 nm and is equipped with a 20 mm aperture.
The scan head is designed for digital signal transfer via the integrated digital servo electronics with SL2-100 interface.

The scan head is equipped for cooling of the mirrors with compressed air and for water cooling of the entrance aperture and electronics. Appropriate connections for water and compressed air are provided on the housing.

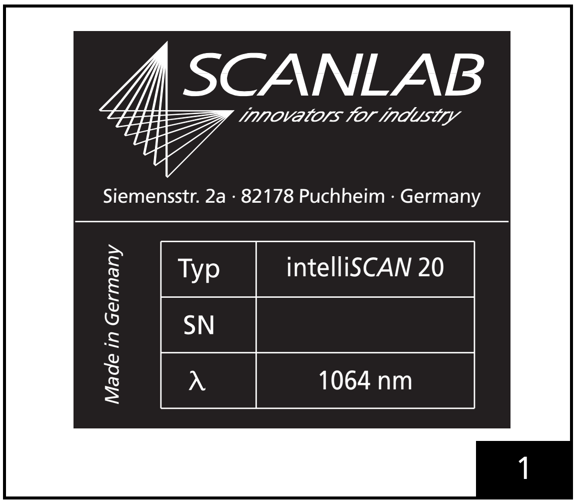
The technical specifications of the product are summarized on page 45.

1.2 Unpacking Instructions and Typical Package Contents

- Carefully remove the scan head from the package.
- Protect the scan head from dust and other contaminants.
- Keep the packaging, so that in case of repair the scan head can be properly repackaged and returned to SCANLAB.
- Also remove all other articles from the package. Check that all parts have been delivered. Please refer to the corresponding packaging list.
  A scan head package typically includes a product test protocol with test data. For mounting an objective an objective mounting set may be included in the package or already mounted to the scan head. For controlling the scan head, an RTC® control board may be included in the package.

1.3 I.D. Plate

The scan head's I.D. plate (see figure 1) with the scan head's serial number is found on the housing.

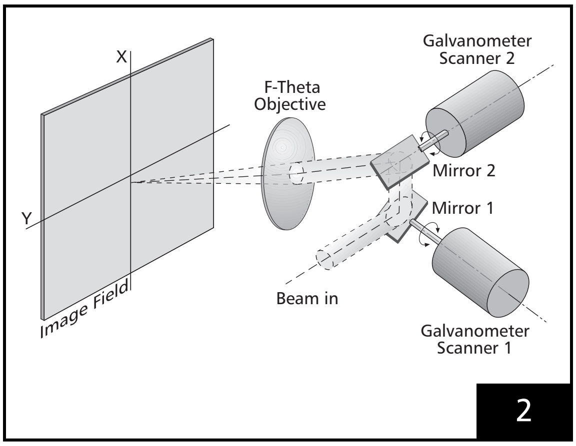


I.D. plate with serial number (SN)

2 The intelli*SCAN* 20 – Principle of Operation

2.1 Dynamic Positioning Laser Beams

The primary tasks of an X-Y scan head are to deflect a laser beam in the X-Y directions and to focus the beam onto the working plane.



Basis of Operation: beam deflection via two galvanometer scanners

The beam deflection task is realized with the help of two tiltable deflection mirrors (see figure 2). The beam enters the scan head through the input aperture and is first deflected in the Y direction by mirror 1 attached to galvanometer scanner 1. The beam then goes on to be deflected in the X direction by mirror 2 attached to galvanometer scanner 2. The resulting deflection angles can be precisely and high-dynamically adjusted by controlling the positions of the galvanometer scanners.

Focusing the beam onto the working plane can be achieved with the help of a scan lens fitted to the scan head's beam exit hole. If an F-Theta objective is used, the position of the focal point on the image field will be directly proportional to the angle of incidence of the beam.

Alternatively, focusing of the beam can be realized with the help of a dynamic focusing system (for instance, SCANLAB's vario*SCAN* 20) positioned in front of the scan head's entrance aperture.

Customized Optical Configuration

To obtain optimum optical performance for a particular laser application, the scan head's optical configuration must meet the requirements of the application and the used laser system. To achieve optimum reflectivity at the mirrors, SCANLAB therefore selects mirror coatings appropriate for the wavelength and power of the user's laser. The size of the mirrors or the scan head's aperture is selected in accordance with the desired spot size and scan speed.

The user, on the other hand, has to ensure that the parameters of the entering laser beam (wavelength, power density and diameter) match the specifications of the scan head.

First the coatings of the deflection mirrors are designed for a defined wavelength or wavelength range. If the wavelength of the employed laser deviates from the specified value, the mirrors will not work properly and can be destroyed.

Second for the mirror coatings also the allowed laser rating is defined. If the specified values are exceeded, destruction of the coatings might result (also see section "Checking the Laser Parameters" on page 32).

In addition the deflection mirrors are intended for a specific beam diameter and a maximum allowed scan angle. If the beam diameter or the scan angle exceeds the specified maximum values, vignetting of the beam can occur. The beam is then no longer fully deflected by the mirrors. A portion of the beam is then absorbed by the scan head, resulting in a loss of power. Furthermore, the interior of the scan head might be damaged due to the absorption of laser radiation.

The amount of possible power loss depends, among other things, on the beam profile of the employed laser. For a Gaussian beam profile, beam vignetting is insignificant when the scan angle of each mirror does not exceed the *maximum allowed scan angle* defined on page 45 and when the diameter of the beam doesn't exceed the specified aperture.

> **Caution!**
>
> - Make sure the aperture and the coatings of the deflection mirrors meet the requirements of your application (see "Technical Specifications" on page 45). For information on tolerances and deviations, please contact SCANLAB.
> - Check if the wavelength of the input beam and the maximum ratings for beam diameter and laser power match the specifications of the scan head (see page 45).
> - When using scan angles larger than the *maximum allowed scan angle* indicated on page 45, some vignetting inside the scan head can occur and damage to the interior of the scan head might result. If your application requires larger scan angles, then please contact SCANLAB.
> - The maximum allowed scan angle is derived from the geometric and optical data of the employed components (see the section "Customized Optical Configuration" on page 6). In some cases, particularly with sufficiently small calibration angles, the maximum allowed scan angle can be larger than the maximum adjustable angle. In such cases, the specified maximum allowed scan angle has no practical relevance.

2.2 Scan Head Control

Data Transmission between the Controller and the Scan Head

The controller and the scan head are interconnected via a serial interface for digital data transfer. Data transmission follows the SL2-100 protocol. In the process, essentially the following signals are transferred:

- The controller delivers position values, i.e. (20-bit) set values for the X and Y axes.
- The scan head generates data signals to be returned to the controller.

The scan head can be operated via a SCANLAB RTC®5 control board (RTC®5 PC interface board or RTC®5 PC/104-*Plus* board) but not via an older RTC® board as an RTC®3, RTC®4 or RTC® *SCAN*alone. The SL2-100 protocol supports the full functionality of the intelli*SCAN*'s digital servo architecture. This allows, for instance, separate, simultaneous evaluation of the X and Y returned data signals.

Position Signals, Image Field and X-Y Reference System

Position signals are digitally transferred from the controller to the scan head.

Figure 3 shows the definition of the X-Y reference system which is used for the position signals transmitted to the scan head. The orientation of the axes corresponds to the orientation used by the RTC® boards from SCANLAB: The Y axis points in the opposite direction of the entry beam (and the Z axis in the opposite direction of the exit beam). Consequently: Scanner 1 deflects the beam in the Y direction, Scanner 2 in the X direction.

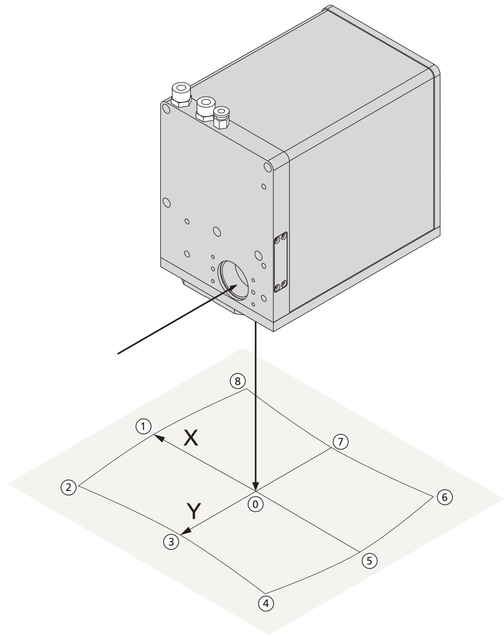
The scan head is calibrated in such a way that for a scan angle of 0.408 rad optically with excursion in the negative axis direction the bit-value "–503316" has to be transmitted, for the neutral position (null point) the bit-value "0, and for a scan angle of 0.408 rad optically with excursion in the positive axis direction the bit-value "+503316".

The maximum adjustable scan angle is (1 / 0.96) larger than the calibration angle. The input signal values for the maximum adjustable image field points (see figure 3) are listed in the following table.

Position	X Bit-Value	Y Bit-Value
0	0	0
1	524287	0
2	524287	524287
3	0	524287
4	–524288	524287
5	–524288	0
6	–524288	–524288
7	0	–524288
8	524287	–524288

Vignetting can occur at a particular scan angle dependent on the specific scan head and objective. The laser beam is then partially blocked within the scan head or objective, which results in transmission losses. The higher the power loss, the greater is the risk of damage to the scan system. In view of this, the technical specifications page 45 include not only the calibration angle, but also the maximum allowed scan angle. This is not the same as the maximum adjustable scan angle. To avoid scan system damage, make sure the maximum allowed scan angle is never exceeded.

The maximum allowed scan angle is derived from the geometric and optical data of the employed components (see the section "Customized Optical Configuration" on page 6). In some cases, particularly with sufficiently small calibration angles, the maximum allowed scan angle can be larger than the maximum adjustable angle. In such cases, the specified maximum allowed scan angle has no practical relevance.



3

Positions in the image field

Figure 3 also depicts the pillow-barrel-shaped distortion of the square image field and shows the orientation of this distortion with reference to the axes. The field distortion is caused by the beam path within the scan head and by the characteristics of the objective. It must be compensated by the controller.

If you use a SCANLAB RTC® control board for controlling the scan head, the field distortion is compensated automatically. Before data values are transferred to the scan head, the values are transformed by the RTC® boards with the help of a correction table. A correction table specific for your system is included in the RTC® software package or can be ordered from SCANLAB (also refer to the RTC® manual). You can use positive and negative coordinate bit-values (–524288 to +524287) of an ideal image field, based on the reference system shown in figure 3, with the origin (zero point) in the center of the image field. The RTC® board calculates the corresponding input values and transfers them to the scan head.

The image field size, as well as the working distance A between the input laser beam and the nominal working plane, depend on various factors – among them the focal length of the objective and the aperture of the scan head. The divergence of the input beam also has an influence on the working distance A.

Returned Signals

The intelli*SCAN*'s digital servo architecture allows a wide variety of data signals to be returned to the control board. Via the return channel (DATA OUT±), data are transmitted to the controller board every 10 µs simultaneously for both axes (in compliance with the SL2-100 protocol). This opens up possibilities such as monitoring the galvanometer scanners' actual values during execution of an application or carrying out comprehensive troubleshooting in case of operational malfunction.

The scan head returns the following signals to the control board every 10 µs:

- a 20-bit status word:
  When the scan head is operated via an RTC®5 control board, the command **control_command** can be used for selecting which data the scan head should return to the control board via the 20-bit status word. The selected data sources will be transmitted until another source is selected. By default, after every reboot or reset, the XY2-100 status word (see below) is returned via the 20-bit status word.
- 6 additional status bits:
  Via these status bits, the scan head returns to the control board (independently on the selection via **control_command**) the PWROK, TempOK and PosAck status informations of the XY2-100 status word (see below).

Data received by the RTC®5 board can be synchronously or asynchronously read at any time via **get_head_status**, **get_value** or additional commands (see the RTC®5 manual).

XY2-100 Status Word

By default, starting from five seconds after every reboot or reset, the XY2-100 status word is returned via the 20-bit status word. The status word contains three status values, which are also returned (continuously and independently on the selection via **control_command**) via the six additional status bits:

- PWROK (i.e. "Power OK")
  PWROK = 0 signifies a problem in the power supply. In normal operation, the PWROK signal is 1. If the signal switches from 1 to 0 during operation, then **the laser must be turned off immediately**. Under some circumstances the system could deflect the laser beam in an unintended

direction, which may cause health hazards and severe equipment damage. The system should be checked immediately to determine the cause (also see section "Power Supply" on page 29).

- TempOK (i.e. "Temperature OK")
  The TEMPOK signal always switches from 0 to 1 when the operating temperature has been reached (which might take a few minutes). If, during operation, the galvo temperature drops below its minimum operating temperature or exceeds a maximum allowable temperature, the TEMPOK signal will switch to 0. In this case, system operation does not need to be stopped immediately, but large drift or other side-effects may occur.

  If system operation is not stopped and the scanner temperatures then reach a still higher critical value, then the built-in temperature control mechanism will switch off the galvanometer scanner drive stages to avoid heat-induced damage to the scanners or the head (see page 14). If the scanner temperature drops again below the power-down threshold, the scanner drive stages are automatically restarted.

- PosAck (i.e. "Position Acknowledge")
  PosAck = 1 signifies that the difference between the set value and the real position is less than 0.28% of the maximum adjustable image field size (see page 8). The PosAck signal normally switches to 1 within a few seconds after power-up. The PosAck signals of the X and Y axis are logically AND-connected and returned as common signal. The command **control_command** allows to set the PosAck threshold value (see chapter 6.3, "Process Monitoring", on page 38).

Additional Data Types

When the intelli*SCAN* is operated via an RTC®5 board, the command *control_command* (see the RTC®5 manual) can be used for selecting which data the scan head should return to the control board. Unless the configuration is changed after reset, the XY2-100 status word will be transferred (see the previous section). The selected data is transmitted at 10 µs intervals until a different data type is requested.

The following is a description of the data types that may be selected. The data can and must be separately evaluated for each axis.

XY2-100 Status word

See the previous section.

Actual Position

Actual angular position of the corresponding axis

Set Position

Set angular position of the corresponding axis

Position Error

Set angular position - Actual angular position (difference between the current actual angular position and the current set angular position of the corresponding axis)

Actual Current

Actual galvo output stage current of the corresponding axis

Relative Galvo Control

Galvo control voltage (in per mille of the maximum value)

Actual Velocity

Actual angular velocity of the corresponding axis

Operational Status

The intelli*SCAN* provides various blocks of extended status informations.

If the first block is selected to be returned to the control board, then the scan head provides the following information about the current operating state:

- Status of galvo output stage (on/off)
- Status of galvo heater output stage (on/off)
- Status of internal voltages (all voltages o.k. or at least one internal voltage not o.k.)
- Status of external voltage (o.k. or power supply interruption)
- Status of AD converter (successfully initialized or not initialized)
- Status of booting process (complete or not yet completed)
- Status of control parameters (valid or invalid).
- Boot signal: The control is activated, as soon as all necessary flags are set
- Status of positioning (positioning error within the allowed range (< 0.28%) or not in the allowed range)
- Status of positioning (positioning within the allowed range or critical position reached)
- Temperature Status (operating temperatures of galvanometer scanner and servo board reached or not yet reached)
- Temperature Status (temperature of galvanometer scanner and servo board below a critical value or at least one of the two temperatures above the critical value): If one of the two temperatures exceeds the critical value, then the intelli*SCAN* automatically enters a temporary temperature error state: the output stages of the affected axis are (temporarily) deactivated. The scan head resumes normal operation, as soon as the temperature drops below the maximum allowed value.
- Error Status (no critical error or system presently in critical error state). Critical errors are for instance:
  - improper internal voltages
  - external power supply interruption
  - reaching a critical edge position

  If a critical error occurs, the scan head automatically enters a permanent error state, in which the output stages of the affected axis remain deactivated – even if the critical error was only temporarily present. Normal operation is *not* resumed.

Note:
During both temporary and permanent error states, the scan head will continue to transmit data to the control board. Even in these states, switching or selection of data signals for diagnostic purposes is still possible.

The second information block can be selected to be returned to the control board if more detailed information about the current operation state is desired. This block separately indicates potential error states of the various internal voltages and of the galvanometer scanner and servo board temperature.

Alternatively, two further information blocks can be selected to be returned to the control board: They indicate the operation states listed above at the moment of the most recently occurred operation interruption. After every successful restart – and, as long as no error has occurred – all status informations of these two blocks are irrelevant. Only, as soon as an error causes a switch into a temporary or permanent error state, the current status values will be saved into these blocks. Simultaneously, also an event code is set, indicating which particular event caused the error state. This event code can be read out separately.

Temperature

For each axis, the following temperatures can be returned to the control board:

- Temperature of the corresponding galvanometer scanner
- Temperature of the corresponding servo board

Internal Voltages

For each axis, the following internal voltages can be returned to the control board:

- AGC (automatic gain control) voltage: supply voltage of the corresponding position detector
- DSP core supply voltage (1.8 V)
- DSP IO voltage (3.3 V)
- Analog section voltage (9 V)
- AD converter supply voltage (5 V)

Exact values for the internal voltages can vary for different scan head versions.

Internal Current

For each axis, the AGC current (automatic gain control) of the corresponding position detector can be returned to the control board.

Heating Output of the Galvo Heaters

Relative heating output (0 to 1000 per mille) of the corresponding galvanometer scanner's heater.

General Scan Head Information

Alternatively, the following data types may be selected at both axes:

- Serial number
- Article number
- Firmware version number
- Calibration
- Aperture
- Wavelength
- Running time

Configuring the Servo and Start Behavior

The intelli*SCAN* allows to configure a number of settings. If used together with an RTC®5 board the configuration can be realized via the command **control_command** (see the RTC®5 manual).

The user can

- select the data type to be transmitted from scan head to the controller (see section "Returned Signals" on page 9),
- select an appropriate dynamic configuration (see chapter 6.1, "Dynamics Configuration (Tuning)", on page 35 and chapter 9, "intelliSCAN 20 Technical Specifications", on page 45),
- set a desired PosAcknowledge threshold value (see chapter 6.3, "Process Monitoring", on page 38),
- change the scan head's effective calibration (see chapter 6.4, "Configuring the Effective Calibration", on page 39),
- configure the scan head's start behavior (see chapter 6.5, "Configuring the Start Behavior", on page 39) and
- perform a fault diagnosis or verify intact data transfer capability (see chapter 8.1, "Fault Diagnosis and Functional Test", on page 44).

2.3 Internal Protective Functions

Assuring Reliable Power Supply

For safe scan head operation, a reliable supply of power is absolutely essential. If the supply voltages deviate excessively from their specified values or if the mechanism for switching on power does not result in symmetrical turn-on of the supply voltages, then unintended scanner movements may occur. This in turn can damage the scanners and deflection mirrors and can lead, if the laser is on, to beam deflection in unintended directions.

The intelli*SCAN*'s supply voltages are monitored by the intelli*SCAN*'s digital servo electronics. If, during operation, the supply voltage falls below a minimum of approx. 25 V (e.g. due to excessively long or thin cables, a weak power supply or high loads), then the electronics disconnects the scan head from the power supply. In order to restart scan head operation, the supply voltage problem must then be resolved and the scan head switched off and then restarted.

Monitoring Scan Range and Proper Scan Operation

The intelli*SCAN* has a built-in monitoring function to prevent damage to its galvanometer scanners or electronics when a problem occurs.

If a galvanometer scanner's scan angle exceeds the allowed range due to an operational disturbance or if the galvanometer scanner is not moved to its set position within a certain time, its output stage will be shut down. In such situations, the galvanometer scanner can no longer be controlled.

Danger!

- If an output stage is shut down due to a scan range overrun or any other problem, laser power must be switched off immediately. Otherwise, health hazards and severe equipment damage can occur due to uncontrolled laser radiation.

Assuring Safe Operating Temperatures

If the scanners are driven for long periods of time at high positioning speeds or if the application includes a high rate of vector changes, the correspondingly high current consumption of the galvanometer scanners can lead to excessive temperatures – especially in the case of insufficient cooling, for instance due to a weak thermal link to the machine.

To prevent damage to the scanners, the intelli*SCAN* 20 provides a two-stage temperature control mechanism.

Caution!

- The user must ensure that the application program evaluates the temperature control signals correctly, as described below.

Stage 1: Temperature Status Warning

The temperature status signal TempOK indicates that the scanner is operating at a safe temperature level. During normal operation, the signal is 1.
If the scanner temperature rises above a certain value or drops below a minimum value, then the TempOK signal switches to 0. If the TEMPOK signal switches to 0 during operation, system operation should be stopped and the system should be checked to determine the cause. If system operation is not stopped, large drift or other side-effects may occur.

Stage 2: Critical Temperature Shutdown

In addition to the temperature status warning, the following scanner protective function is implemented:

If a scanner's temperature rises above the critical value for temperature status warning and reaches a second, still higher critical value, then the scanner's output stage is turned off to prevent damage to the scanner. In this situation, the scanner's position is stationary and no longer under programmatic control.

If the scanner's temperature drops again below the power-down threshold, the scanner's drive stage is automatically restarted and the scan head will resume normal operation.

3 Safety During Installation and Operation

To reduce the risk of injury, please observe the following guidelines.

The safety and warning notices in this manual are indicated by a symbol set against a gray background:

Instructions that may affect a person's health are marked with a warning triangle next to the word "Danger".

Instructions that recommend appropriate use of this device or warn of damage that may occur to it are identified by a circle with an "X" in it, next to the word "Caution".

3.1 Operational Guidelines and Standards

When operating the scan head, the following guidelines and standards should be followed:

- EC Guideline 73/23/EEC
  Low Voltage Directive
  (including amendment 93/68/EEC)
- EC Guideline 89/336/EEC
  Electromagnetic Compatibility
  (including amendments 91/263/EEC, 92/31/EEC, 93/68/EEC and 2004/108/EU)
- EC Guideline 98/37/EU
  Machinery Directive
- EN 60204-1 (November 1998)
  Safety of Machinery – Electrical Equipments of Machines, Part1: General Requirements
  (also see similar general machinery safety standards such as VDE 0113-1, IEC60204-1 or ANSI B11.19 Machine Tools – Safeguarding When Referenced by Other B11 Machine Tool Safety Standards-Performance Criteria for the Design, Construction, Care and Operation)
- EN 60825-1 (October 2003)
  Safety of Laser Products, Part 1: Equipment Classification, Requirements and User's Guide
  (also see similar general laser safety standards such as VDE 0837-1, IEC 60825-1, Safety of Laser Products - Part 1: Equipment Classification, Requirements, and User's Guide, 21 CFR 1040, Laser Product Performance Standard or ANSI Z136.1 Standard for the Safe Use of Lasers)
- EN 12626
  Safety of Machinery - Laser Processing Machines - Safety Requirements
  (also see similar laser materials processing system safety standards such as ISO 11553, Safety of Machinery - Laser Processing Machines - Safety Requirements, IEC 60825-4, Safety of Laser Products - Part 4: Safety of Laser Products or ANSI B11.21-1997, Machine Tools Using Lasers for Processing Materials - Safety Requirements for Design, Construction, Care, and Use)

Additional application-dependent guidelines and standards may apply.

Complying with the Relevant Standards for the CE Label

The intelli*SCAN* 20 is delivered as an OEM component conceived of for integration into a laser scan system.

The system manufacturer bears the responsibility for complying with the standards and guidelines required for equipment usage and for the CE label.

Scan Head Conformity to EC Guidelines for Electromagnetic Compatibility (EMC)

The scan head is in conformance with EC guidelines 89/336/EEC (electromagnetic compatibility).

Electromagnetic fields that exceed these standards can affect the operation and operating safety of the scan head and therefore require special shielding.

For more information, see the section "Electromagnetic Compatibility" on page 46.

3.2 Laser Safety

This scan head is designed to be operated in conjunction with a laser. Therefore, all applicable rules and regulations for safe operation of lasers must be known and applied when installing the scan head and operating the system in which it is used. Since SCANLAB has no influence over the employed laser or the overall system, the customer is solely responsible for the laser safety of the entire system.

Danger!

- Safety regulations may differ from country to country. The customer bears sole responsibility for compliance with all applicable safety regulations of their respective regulatory jurisdiction.

Shutter

The scan head has no shutter and there is no device to decrease the laser output power. It is the responsibility of the customer to include such a device in the system in a way as to comply with all regulations. The observance of laser safety must be ensured for the entire system.

Maintenance

During maintenance of the laser equipment, the class of the laser can increase. Therefore, the customer must take suitable protective measures.

Warning Symbols

The area where the emerging beam is harmful must be marked with a warning symbol indicating the class of the employed laser – in accordance with IEC 60825-1 laser safety requirements. In addition, a warning symbol must be placed at the emitting aperture of the laser system. The table on page 17 shows the appropriate warning symbols for the various laser classes specified by IEC 60825-1 (or EN 60825-1 / VDE 0837 T1).

Danger!

- During assembly or operation of the scan head, never stare directly into the laser beam or its deflected radiation. Keep all parts of the body away from the laser beam and its path. Routine maintenance should be performed as described in "Routine Maintenance of the Optical Surfaces" on page 40 and all safety instructions should be observed!
- Adjust the output beam path of the scan head by means of a Class 2 laser. If this is not possible, the laser should be operated at the lowest power. Avoid dangerous deflected radiation!
- The risk of hazardous deflected radiation can increase when optical instruments are used in combination with the scan head.
- Before checking the scan head, make absolutely certain that the laser and scan head are turned off!
- Cover the path of the laser beam via an appropriate protecting case to block laser radiation!
- Do not obstruct the movement of the scan head's mirrors in any way. When the scan head is turned on, the mirrors must not be touched at all!
- Closely follow all IEC 60825-1 laser safety requirements and other applicable accident prevention regulations of your respective regulatory jurisdiction.
- Wear appropriate eye protection at all times.
- Always turn on the PC controller and the scan head's power supply first before turning on the laser. Otherwise the laser beam might be reflected in an arbitrary direction.

Laser Classes Specified by IEC 60825-1 (or EN 60825-1 / VDE 0837 T1)

Visible Laser Radiation	Invisible Laser Radiation	Potential Hazards
LASER CLASS 1	LASER CLASS 1	Class 1: This laser radiation is not harmful; is eye-safe.
 LASER RADIATION DO NOT STARE DIRECTLY INTO THE BEAM WITH OR WITHOUT OPTICAL INSTRUMENTS LASER CLASS 1 M	 INVISIBLE LASER RADIATION DO NOT STARE DIRECTLY INTO THE BEAM WITH OR WITHOUT OPTICAL INSTRUMENTS LASER CLASS 1 M	Class 1 M: Exposure to this radiation is harmful to the eyes if optical instruments are used to reduce the cross section of the laser beam. If this is not the case, this laser radiation is not harmful; is eye-safe.
 LASER RADIATION DO NOT STARE DIRECTLY INTO THE BEAM LASER CLASS 2		Class 2: This laser radiation is in the visible spectrum of 400 to 700 nm. Exposure to this radiation for less than 0.25 s is not harmful to the eyes. It is eye-safe due to the eye's natural aversion response and blink reflex.
 LASER RADIATION DO NOT STARE DIRECTLY INTO THE BEAM WITH OR WITHOUT OPTICAL INSTRUMENTS LASER CLASS 2 M		Class 2 M: This laser radiation is in the visible spectrum of 400 to 700 nm. Exposure to this radiation is harmful to the eyes if optical instruments are used to reduce the cross section of the laser beam. If this is not the case, exposure to this radiation for less than 0.25 s is not harmful to the eyes and is eye-safe due to the eye's natural aversion response and blink reflex.
 LASER RADIATION AVOID EXPOSURE OF THE EYES LASER CLASS 3 R	 INVISIBLE LASER RADIATION AVOID EXPOSURE TO THE LASER BEAM LASER CLASS 3 R	Class 3 R: This laser radiation is harmful to the eyes. Eye exposure exceeds the maximum allowable value.

Visible Laser Radiation	Invisible Laser Radiation	Potential Hazards
 LASER RADIATION AVOID EXPOSURE TO THE LASER BEAM LASER CLASS 3 B	 INVISIBLE LASER RADIATION AVOID EXPOSURE TO THE LASER BEAM LASER CLASS 3 B	Class 3 B: This laser radiation is harmful to the eyes and in some cases to the skin.
 LASER RADIATION AVOID ANY EXPOSURE OF THE EYES OR THE SKIN TO DIRECT OR SCATTERED RADIATION LASER CLASS 4	 INVISIBLE LASER RADIATION AVOID ANY EXPOSURE OF THE EYES OR THE SKIN TO DIRECT OR SCATTERED RADIATION LASER CLASS 4	Class 4: This laser radiation is very harmful to the eyes and skin. Stray radiation can also be dangerous. This radiation can cause fire or explosion and the generation of toxic gases or vapors.

3.3 Electrical Safety

Power is furnished to the scan head by a user-supplied low voltage power supply. The power supply must meet the following mains insulation requirements:

- If the connectors are covered and cannot be reached without tools from the outside, single insulation between the mains and the low voltage circuit is sufficient. The mains insulation must be able to withstand a test voltage of 2 kV AC applied between the mains and the low voltage circuit.
- If the connectors can be reached from the outside, double or reinforced insulation between the mains and the low voltage circuit is necessary. The mains insulation must be able to withstand a test voltage of 4 kV AC applied between the mains and the low voltage circuit.

Additional application-dependent guidelines and standards may apply.

4 Installation

Follow each step for preparation, mounting and electrical connection in the correct order as described in this chapter.

Danger!

- Make sure all components of the system (laser, controller, power supply, computer) are switched off before installation.
- During installation of the scan head, never stare directly into the laser beam or at any of its deflected radiation.
- Never place parts of the body into the direct path of the laser or its deflected radiation.
- After the scan head has been mounted, there is a cone-shaped hazardous laser output area. Do not stare into the laser or its deflected radiation. Keep all parts of the body away from the laser beam.
- Always turn on the PC controller and the scan head's power supply first before turning on the laser. Otherwise the laser beam might be reflected in an arbitrary direction.

Caution!

- Carefully take the scan head out of the packaging.
- Protect the scan head from dust and other contaminants.
- Never touch the optical surfaces of the deflection mirrors. Always use gloves and/or special lens cleaning tissues when handling the optical components.
- Follow the procedures in chapter 7.1 for periodically checking and cleaning the optics.

4.1 Checking the Specifications

Make sure the specifications of the scan head meet the requirements of your application (see "Technical Specifications" on page 45). If your application requires other specifications, then please contact SCANLAB.

4.2 Mounting the Objective

If the scan head is to be operated with an objective which is not factory-installed (or if an already-mounted objective is to be exchanged), then proceed as described in the following sections.

Objectives are mounted either directly or via an objective holder onto the housing's beam exit side. Many objectives require a mounting set, which (in addition to an objective holder) can include components for securing the objective and objective holder, as well as seal rings and space rings to ensure a safe distance between the objective and the deflection mirrors. Different objectives might require different mounting sets. Appropriate objective mounting sets are attached on the scan head, included with the objective, or obtainable from SCANLAB.

Objective Holder

If the objective mounting set includes an objective holder, install it as follows.

- Carefully remove (e.g. with a small screw driver) any protective covers from the scan head's objective opening.
- Some setups require installation of one or more seal rings between the housing and the objective holder. Check for corresponding accessories in the objective mounting set.
- Place the objective holder (with its form-fitting bottom side) in the beam exit opening. Ensure that the objective holder is correctly positioned. A tilted objective holder can produce unintended beam paths.
- Secure the objective holder onto the beam exit side via four screws.

Objective

Caution!

- Before installing the objective, verify its compatibility with the mounted objective holder or beam exit threads. Otherwise, damage to the objective and scan head mirrors may result. In the event of questions, contact SCANLAB.

Before mounting, inspect the objective for scratches, lens defects and dirt. If necessary, clean as described in "Routine Maintenance of the Optical Surfaces" on page 40.

Mount the objective as follows:

- Carefully remove (e.g. with a small screw driver) any protective covers from the objective holder or the scan head's objective opening.
- Remove the protective cover from the objective's beam entrance side.
- Some setups require installation of one or more seal rings between the objective holder and the objective. Seal rings should be lightly lubricated (with vacuum grease). Otherwise, threading of the objective might be very difficult. Additionally, some setups require installation of one or more space rings between the objective holder and the objective to ensure a safe distance between the objective and the deflection mirrors. Check for corresponding accessories in the objective mounting set.

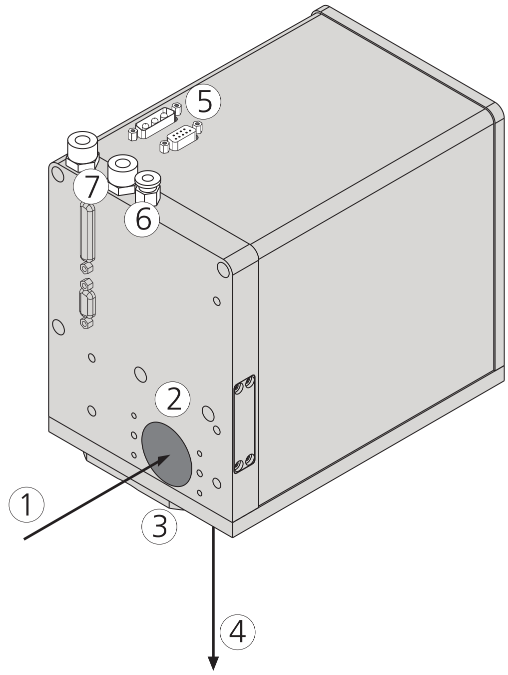
Caution!

- When installing the objective, ensure that all components of the corresponding objective mounting set are used. Failure to install included seal or space rings can lead to a mirror crash (resulting from inadequate distance between the deflection mirrors and the objective). Furthermore, the beam exit might not be optimally sealed.

- Some objectives are secured to their holders via screws (and washers). However, most objectives are directly screwed into the objective holder. Before screwing in the objective, lightly lubricate its threads (e.g. with vacuum grease) to prevent cold welding between the objective and its holder.

4.3 Layout and Dimensions

Figure 4 shows the layout of the scan head with the electrical connectors and the connections for air and water cooling.



Legend

1 Entering beam
2 Beam entrance
3 Objective
4 Emerging beam
5 Electrical connections
6 Connection for compressed air
7 Connections for cooling water

4

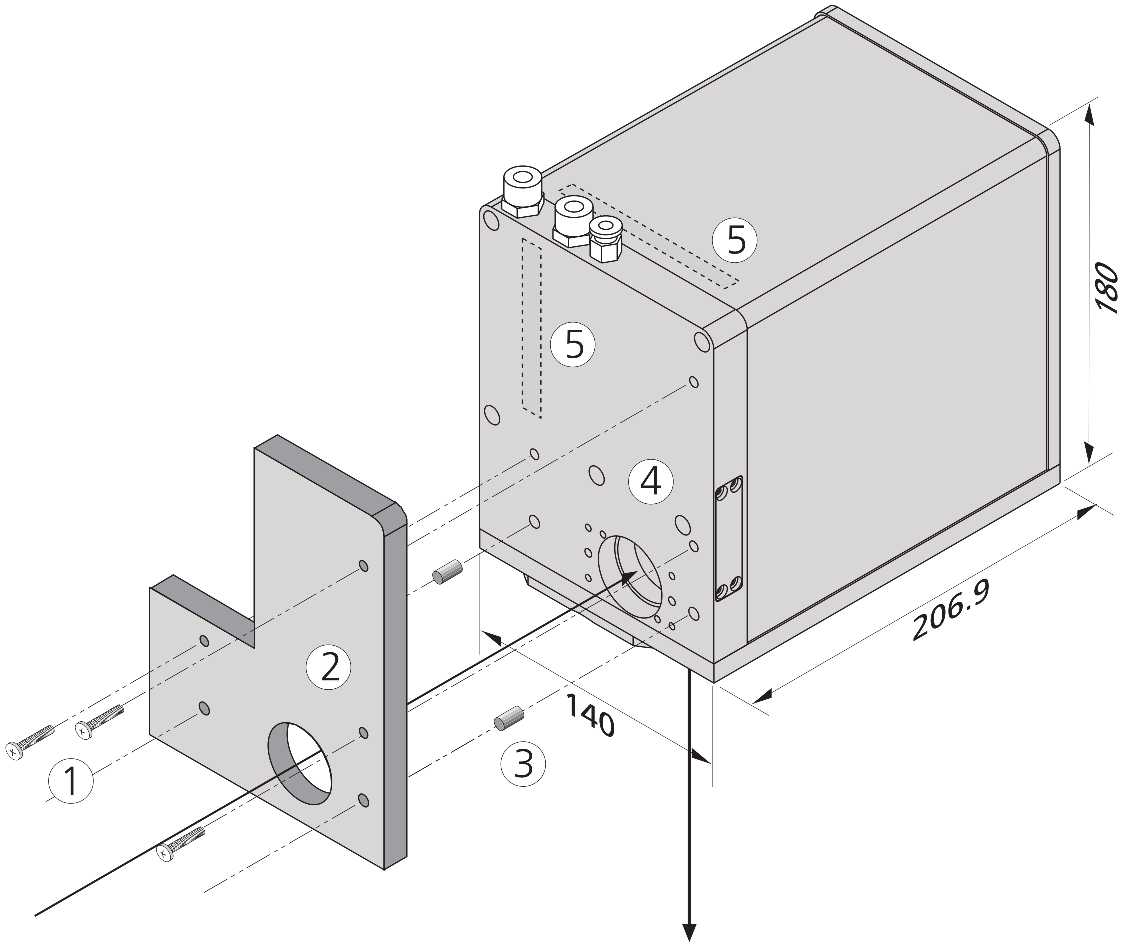
Scan head overview with connector position

Figure 5 on page 22 shows the scan head with its outer dimensions and the parts which are important for mounting. The scan head installation is described in chapter "Mounting the Scan Head", on page 26.

Figure 6 on page 23 and figure 8 on page 25 show the dimensions necessary for mounting the scan head and adjusting the scan head with respect to the working area. Figure 6 depicts the scan head's mounting surface with its mounting bore holes and a bottom view of the scan head (beam exit side) which shows the displacement of the entry beam axis from the beam exit axis (The deflecting mirrors are in their neutral positions).

Figure 8 shows the following distances:

- the working distance A
- the distance B between the axis of the input beam and the lower edge of the housing
- the distance C between the axis of the input beam and the lowest edge of the objective or its enclosure.
- the diameter D which is the larger of the diameters of the objective and its enclosure.
- the distance E between the front edge of the beam entrance side and the axis of the beam exiting the scan head.



Legend

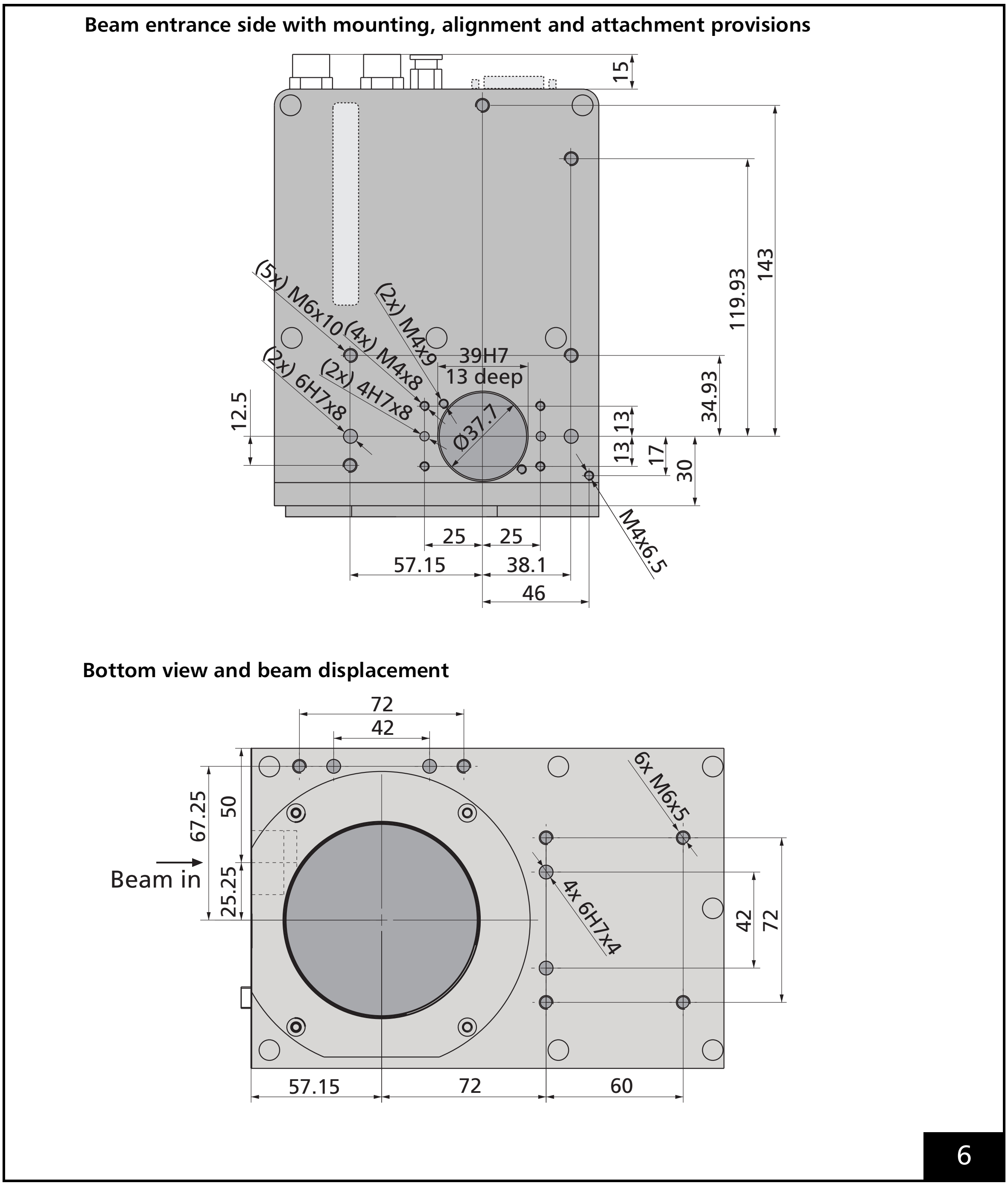
1 Mounting screws *
2 Laser system flange *
3 Alignment pins *
4 Beam entrance side with mounting bore holes

(* not included)

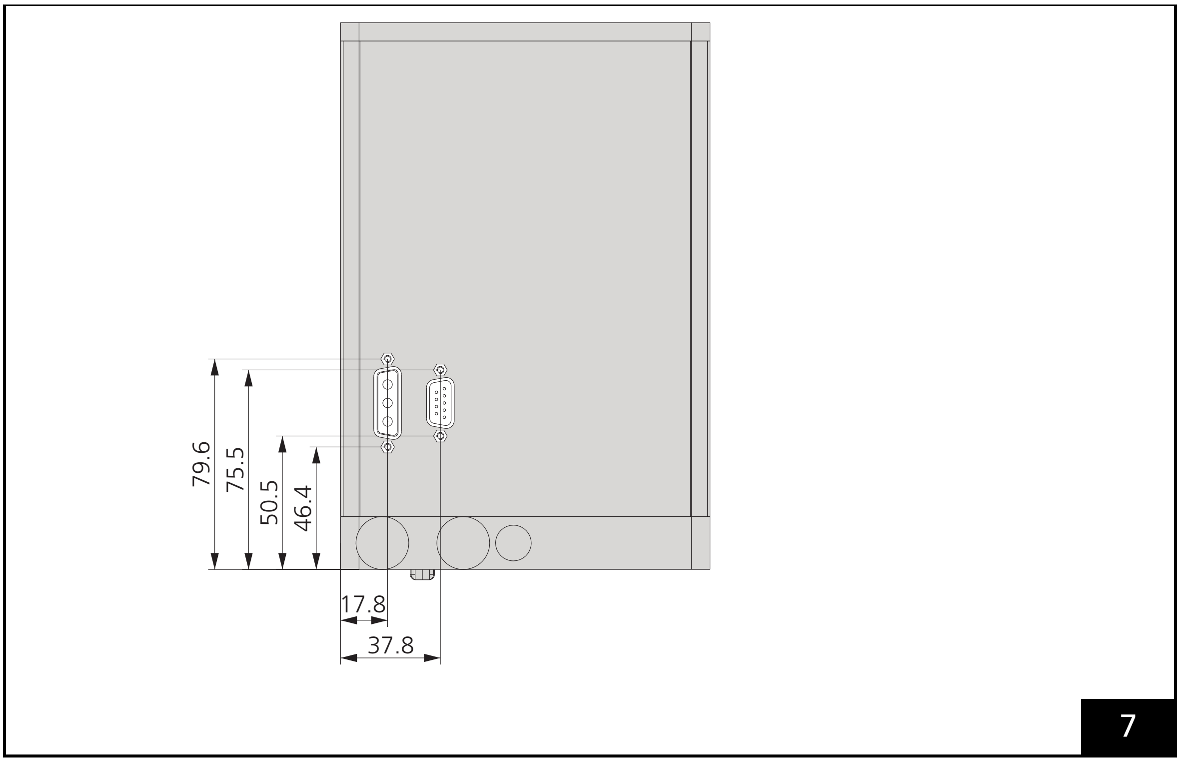
5 Possible positions of electrical connectors (the actual connector type and position of this scan head are shown in figure 4)

5

Scan head with mounting assembly (all dimensions in mm)



Beam entrance side and bottom view (all dimensions in mm)



Top view of the scan head with position of the electrical connectors (all dimensions in mm)

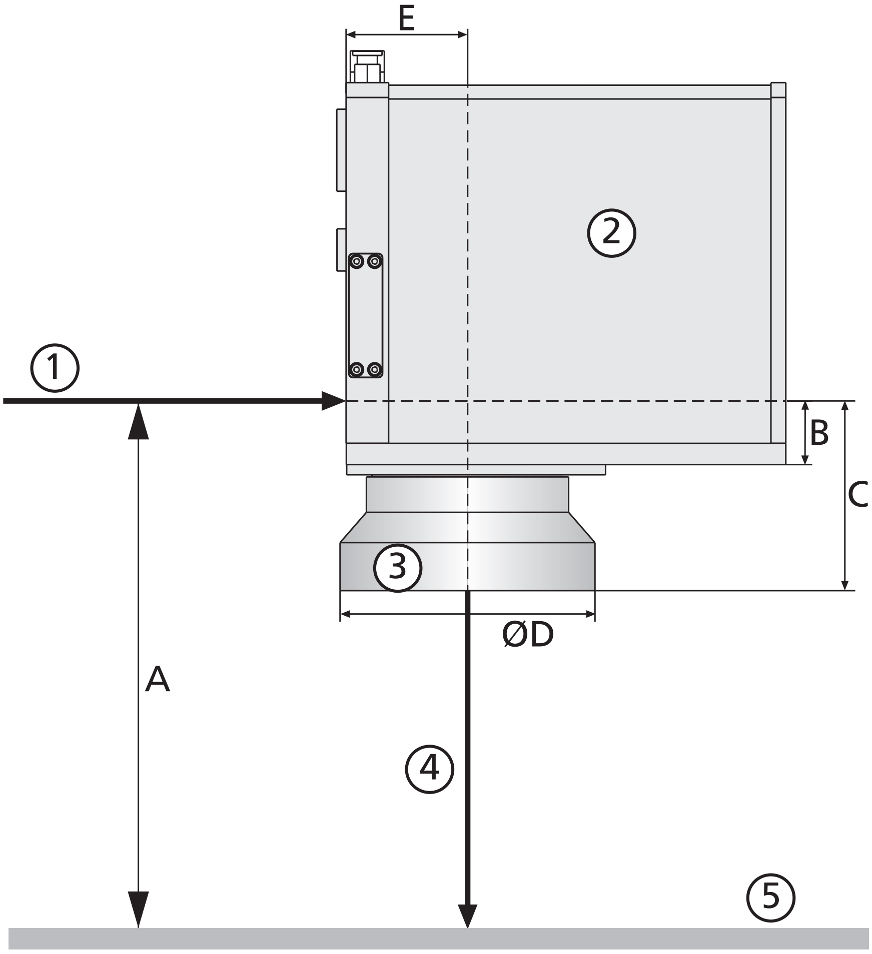
Legend

1 Beam entrance
2 Scan head
3 Objective (not shown true-to-scale)
4 Emerging beam
5 Image field

Dimensions

B = 30 mm
E = 57.15 mm

Note: drawing not true-to-scale



8

Working Distance A, distances B-E (see chapter 4.4) and dimensions (intelli*SCAN* 20)

4.4 Mounting the Scan Head

The illustrations for this section are found in the previous section, starting on page 21.

For mounting the scan head, the beam entrance side provides bore holes designed for attachment to a standardized flange on the laser system – see figure 5 on page 22. The laser system flange, alignment pins and mounting screws are not included in the package.

The dimensions of the beam entrance side and its bore holes are shown in figure 6 on page 23. The beam entry position is defined by two 6^{H7} alignment holes on the mounting bracket. The laser beam axis must be identical with the laser input axis of the scan head. To ensure this alignment, the laser system flange must have appropriate holes to accommodate two 6_{h6} alignment pins and three M6-threaded mounting screws.

On designing the attachment flange, also consider the position of the scan head's electrical connections (see figure 4 on page 21).

Mount the scan head in the following manner:

- Carefully remove the protective covering of the laser input hole (e.g. with a small screwdriver).
- Place two 6_{h6} alignment pins in the corresponding 6^{H7} alignment holes on the flange or beam entrance side.
- Place the scan head on the flange so that the alignment pins line up with the alignment holes on the flange and the beam entrance side. This way the scan head is aligned with respect to the laser.
- Fasten the scan head to the flange by installing three mounting screws with M6 threads into the corresponding threaded mounting holes.
- On mounting the scan head consider a correct alignment in respect to the entering laser beam (also see chapter "Adjustment and Alignment", on page 33) and in respect to the working field (also see figure 8 on page 25).

Caution!

- To align and fasten the scan head, only use the alignment and mounting holes depicted in figure 5 on page 22. Other holes cannot be used for aligning and fastening the scan head or for any other purposes.

4.5 Connections for Cooling

The intelli*SCAN* 20 is equipped with connections for water and air. Both water and air cooling are necessary for safe operation. Insufficient cooling can result in serious damage to the scan head.

During operation, the scan head dissipates considerable power. Therefore the beam entry side of the scan head's housing is equipped with water conduits for cooling the entrance aperture and amplifier boards.

Additionally, an air cooling connection is provided for transferring the heat absorbed by the mirrors.

The user must install appropriate air and water inputs and outputs to ensure adequate supply and circulation of cooling air and water.

Caution!

- **Operate the scan head only with appropriate air and water cooling.**
- A water flow rate of approximately 5 l/min. is required at a differential water pressure of $\Delta p < 0.1$ bar and a maximum pressure of $p_{max} = 4$ bar. The water supply should be adjustable.
- An air flow rate of approximately 20 l/min. is required at a differential air pressure of $\Delta p < 2$ bar.
- The cooling air must be dry and totally free of dirt, dust and oil to avoid damaging the optical components. Use appropriate filters.
- To ensure sufficient cooling, both air and water flow should be monitored continuously during operation.
- For storage, make sure to remove all water from the device's water-cooled parts.

Water Cooling

To connect the water supply, suitable adapters and water hoses should be used. SCANLAB recommends 3.2 mm Delrin CPC connectors with automatic stop valves. The CPC connectors can be attached to the housing via the G1/8x10 threads of the cooling water connections. The water hoses should be flexible. They should have an inner diameter of 4 mm and an outer diameter of 6 mm.

- Connect the water hoses to the appropriate connectors at the scan head – see figure 4.
- Connect the water hoses to the water supply. Make sure that the water flow rate can be suitably adjusted.

The temperatures of the water-cooled parts must not exceed 30 °C. The water flow rate has to be adjusted to approximately 5 l/min. The required differential cooling water pressure is $\Delta p < 0.1$ bar at a maximum pressure of $p_{max} = 4$ bar.

Water with anticorrosive agent can be used as cooling liquid. The cooling liquid should be free of copper ions and other heavy metal ions. Otherwise enhanced corrosion of the cooling channels can occur. Also demineralized water mustn't be used.

Air Cooling

The air supply must be attached to the scan head's compressed cooling air connection (see figure 4). From there the air is guided to the two deflection mirrors. The cooling air inlet has a G1/8x10 thread with a screw connector.

To ensure sufficient cooling, an air flow rate of approximately 20 l/min at a differential pressure of $\Delta p < 2$ bar is required. The pressure of the air source should be adjustable.

The cooling air must be dry and totally free of dirt, dust and oil to avoid damage to the optical components. SCANLAB recommends a (normally multistage) dust filter system that provides cooling air in compliance with ISO 8573.1:2001 class 1.6.1. This applies if the supplied air has a temperature of at least 20°C. For lower cooling air temperatures, the dew point should be at least 10 Kelvin lower than the cooling air temperature.

A flexible air hose with an inside diameter of 4 mm and an outside diameter of 6 mm should be used.

4.6 Attachment Provisions

The housing's water-cooled beam entrance side provides a beam entrance with an aperture of 35 mm and a fine-pitched M39x1 thread. Scan heads from SCANLAB are generally delivered with an aperture attached to this fine-pitched thread (see figure 5). The aperture limits the diameter of the input laser beam to a value of 20 mm. The fine-pitched thread can also be used for attaching other apertures or optical components such as focusing lenses. Components attached here should not penetrate further into the beam entrance than the value specified below (the value is correspondingly lower if a penetrating component is also installed at the beam exit).

Four M4-threaded holes and two 4^{H7} alignment holes are available for scan head mounting as well as for attaching fiber optic outputs.

The housing's beam exit side provides a beam exit with an aperture of 87 mm along with six M6-threaded holes and four 6^{H6} alignment holes for alignment and attachment of components such as cross jets, illumination, distance sensors, thermal shields, etc. Components attached here should not penetrate further into the beam exit than the value specified below (the value is correspondingly lower if a penetrating component is also installed at the beam entrance).

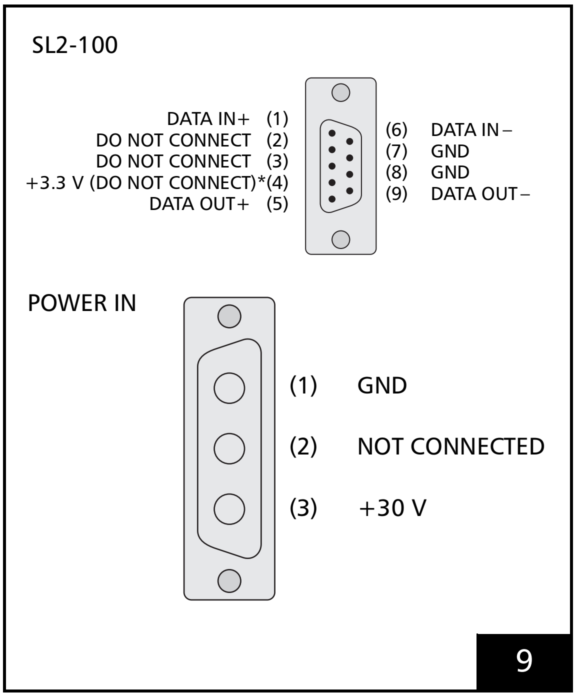
Caution!

- If the beam entrance alone contains an installed component, that component must not penetrate further than 30 mm into the beam entrance.
- If the beam exit alone contains an installed component, that component must not penetrate further than 12 mm into the beam exit.
- If penetrating components are installed at both the beam entrance and beam exit, the maximum allowable penetration depths are correspondingly lower than specified above.

4.7 Electrical Connections

Figure 4 on page 21 shows the location of the electrical connectors on the scan head.

The scan head provides a 9-pin SL2-100 female D-SUB connector for digital data transfer and a 3-pin POWER IN male D-SUB connector (with high power contacts) for power supply. Figure 9 shows the pin assignments of the connectors.



Pin out of electrical connectors
(* see "Data Cable Guidelines", page 30)

Power Supply

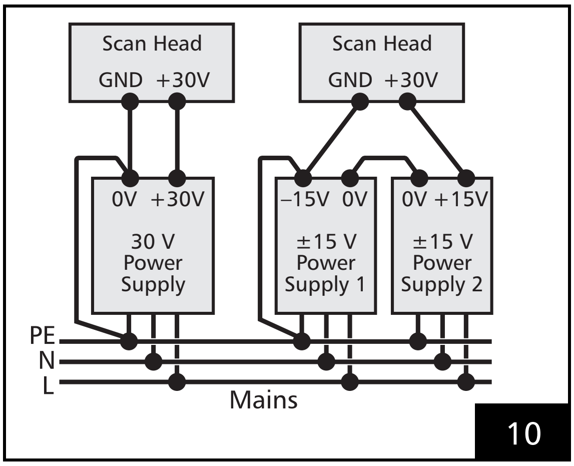
Requirements

The scan head requires a power supply of 30 V (29 - 33 V) or alternatively a balanced source of ±(15+1.5) V DC and a maximum current of 6 A. The residual ripple of the power source should not exceed 100 mV_{pp}.

The intelli*SCAN* provides reverse-polarity protection and start-up current limiting. The power supply and the SL2-100 data interface are galvanically isolated from each other.

The supply voltages are monitored by the intelli*SCAN*'s electronics (see section "Assuring Reliable Power Supply" on page 13).

The scan head can be powered via one 30 V power supply or via two ±15 V power supplies (see figure 10). In general, power supplies are not included in the package, but suitable power supplies are available from SCANLAB. SCANLAB recommends to connect the scan head's GND connection (or the corresponding connection of the power supply's output side) to the mains's grounding wire (PE).



Connect the scan head's GND connection (or the corresponding connection of the power supply's output side) to the mains's grounding wire (PE).

Connections

The power signals should be assigned to the corresponding pins of the scan head's male high-current POWER IN connector (+30 V / GND, see figure 9).

- Make sure each power connection has the correct polarity.
- Connect each pole of the power source via an appropriate cable to all pins of the scan head's connector. The cable connecting the power supply and the scan head must be shielded and should have a cross-sectional area of at least 1.5 mm^2 per pole and a length not exceeding 5 meters. RFI must be minimized by connecting the cable's shielding at one end (utilizing a large surface area) to the power supply's metal shielding and at the scanhead-end to the housing's D-SUB connector.

  – connect the power source GND to the GND pin of the POWER IN connector

  – connect the +30 V power source to the +30 V pin of the POWER IN connector

  or alternatively

  – connect the −15 V power source to the GND pin of the POWER IN connector

  – connect the +15 V power source to the +30 V pin of the POWER IN connector

Caution!

- Before proceeding with wiring the scan head, make sure none of the wires carry any voltages. The control electronics and the computer must be turned off.
- Turn off the power supply before disconnecting the power or the data cable.
- Follow all power supply electrical specifications exactly.

Data Cable Guidelines

Signal transfer between scan head and controller is realized via a data cable. This data cable is connected to the female SL2-100 connector.

The differential DATA IN input channel receives the the control values from the controller. The differential DATA OUT output channel returns the status signals to the controller. The 3.3 V voltage is supplied for SCANLAB's POF converter for optical data transmission (POF = Polymer Optical Fiber) – also see below. This voltage should not be used for other purposes.

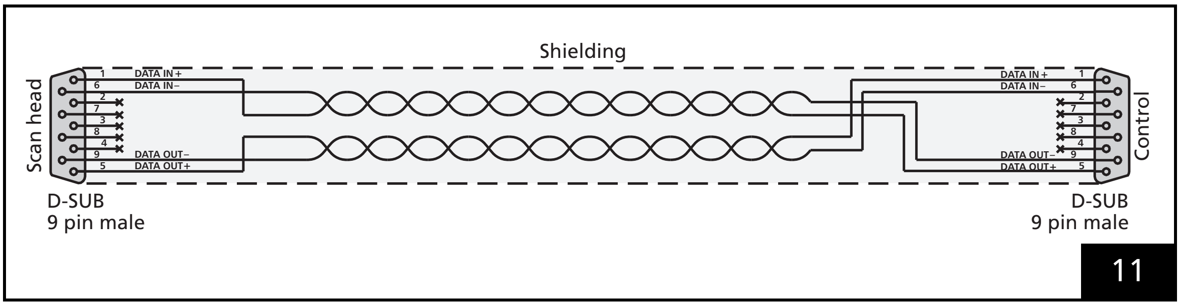
Appropriate data cables, for either electrical transmission or optical fiber transmission, are obtainable from SCANLAB. The optical fiber, too, is attached via a 9-pin D-SUB connector. Optical conversion (POF conversion) for optical data transmission takes place in the D-SUB connector. The operating voltage for POF conversion is supplied at the SL2-100 connector and the RTC®5 board's scan head connectors.

Data cables are generally not included in the package. SCANLAB recommends the following design (for electrical data transmission):

- The cable should be fitted with 9-pin male D-SUB connectors at both ends. The two channels DATA IN± and DATA OUT± (4 wires) must consist of twisted cable pairs and be *cross-connected* at both D-SUB connectors (e.g. so that the RTC®5 board's DATA OUT signal flows to the scan system's DATA IN input). The cable length should not exceed 25 m. SCANLAB recommends a cable impedance of 110 Ω, independent from the cable length.
- The data cable must have coaxial copper braided shielding.
- The D-SUB connectors must have fully shielded metal housings.
- The electrical connection of the cable's braided shielding to the D-SUB housing should *not* be implemented as a wire. Instead, the cable's braided shielding should be *coaxially* connected to the D-SUB housing via shielded clamps.

Figure 11 shows the data cable layout and pin assignments.

- Connect the scan head via the data cable to the customer-specific controller.
- If an RTC® board is used as the controller, then follow the installation instructions in the RTC® manual.



Data cable layout and pin assignments

4.8 Operating and Storage Conditions

For storage, operation and servicing, make sure the following environmental conditions are met:

- The storage temperature for the scan head should be between −35 °C and +60 °C. For storage, make sure to remove all water from the device's water-cooled parts.
- The operating temperature is 25 °C ± 10 °C.
- Protect the scan head from humidity, dust and corrosive vapors to avoid damage to the mirrors, optics and electronics.
- Avoid strong electromagnetic fields and static electricity. These can damage the electronics of the interface and amplifier boards.

Caution!

> Do not operate the scan head without appropriate air and water cooling.

5 Start-up and Operation

5.1 Checking the Installation

Before operating the scan head, carefully check the following:

- Were the mechanical installation and electrical wiring fully and correctly carried out as described in "Installation" on page 19?
- Are all optical components clean and free of dust? If necessary, clean the optical components as described in "Routine Maintenance of the Optical Surfaces" on page 40.
- Are air and water cooling facilities properly connected to the scan head?

Entrance Aperture

The intelli*SCAN* 20's beam entrance usually provides a water-cooled 20 mm brass aperture. For parallel incident laser light, this prevents damage to the scan system due to vignetting at the optical components. For parallel incident laser light and without a focusing optic in front of the intelli*SCAN* 20's beam entrance this water-cooled 20 mm brass aperture from SCANLAB **must** be mounted. In this case the values for the maximum allowed laser power and laser power density, specified in chapter "intelliSCAN 20 Technical Specifications", on page 45 must be considered. If the scan head is delivered without brass aperture, the aperture is available at SCANLAB and can be screwed into the intelli*SCAN* 20's beam entrance or alternatively fixed via two M4 screws and two 4 mm shims with 9.5 mm outside diameter.

However, if the intelli*SCAN* 20 is used in combination with a vario*SCAN* 40_{FLEX}, the 20 mm brass aperture from SCANLAB **must not** be mounted. On the one hand, the optics of the vario*SCAN* 40_{FLEX} expand the laser beam before the beam enters the intelli*SCAN* 20. Therefore a larger entrance aperture is necessary. On the other hand the optics of the vario*SCAN* 40_{FLEX} also focuses the laser beam. The laser beam is formed in such a way that vignetting inside the intelli*SCAN* 20 does not occur. If a focusing optic – such as the vario*SCAN* 40_{FLEX} or another optic designed by SCANLAB – is put in front of the intelli*SCAN* 20's beam entrance, the maximum allowed laser power and laser power density are determined by this focusing optic and are specified in the corresponding manual.

5.2 Checking the Laser Parameters

The scan head's deflection mirrors are designed for a laser beam with defined parameters.

- Compare the technical specifications on page 45 with the requirements of your application. For information on tolerances and deviations, please contact SCANLAB.
- Verify that the input beam wavelength, the input beam diameter and the maximum laser power are compatible with the specifications of the scan head.

Caution!

- The mirror coatings are designed for a laser wavelength of 1064 nm.
- The maximum allowed average laser power is 1000 W (2000 W *).
  The laser power density applied to the mirrors must not exceed the value of 1000 W/cm^2 (2000 W/cm^2 *) continuous wave.
  (* with specified cooling)
- The damage threshold value for pulsed operation is 5 J/cm^2 (for a pulse length of 10 ns and 200 pulses).
- To cope with the heat resulting from high laser power, the scan head is air and water cooled. But if the scan head is used without cooling, damage can result.
- The beam diameter at the entrance of the scan head must not exceed 20 mm.

The values specified for the maximum laser power rating and the laser damage threshold only apply to the scan mirrors. They do not apply to the scan objective or other components. Typically, however, the damage thresholds of scan objectives are similar to that of scan mirrors.

Also be aware that additional optical components in the optical beam path can focus a part of the laser beam onto the mirror and thereby dramatically lower the effective damage threshold. For instance, the lenses or protective window of a scan objective – though coated with an antireflex coating – always reflect a certain fraction of the laser light. If the lenses are shaped such that the reflected laser light is focused onto the scan mirrors, the power density within this focus may be more than 1000 times larger than in the original beam and the effective damage threshold will be correspondingly reduced. In particular, the mirrors can be damaged by lasers with high pulse energies, short pulse lengths and good beam quality. Contamination on or damage to the optical surfaces of the objective or protective window can further increase residual reflectivity, which further increases the danger of mirror damage from back reflections.

Furthermore, the specified values only apply to clean and new mirrors. Mirror contamination (dust, fingerprints, cleaning residue, deposits from laser processing etc.) as well as mechanical damage (scratches, fractures, burn-in, damage by an improper cleaning procedure) can considerably reduce the damage threshold.

The specified damage threshold for pulsed operation is the maximum energy density for which no mirror-surface damage is expected for the specified wavelength and for two hundred pulses with a specified pulse length onto the same mirror spot (see note below).
In general, the damage threshold considerably decreases with an increasing number of laser pulses. In continuous operation, SCANLAB therefore recommends only applying suitably reduced energy densities (depending on the repetition rate and the laser parameters, typically five times smaller than the specified pulse damage threshold, if necessary even smaller).

The damage threshold for pulsed operation also decreases with decreasing pulse length. In particular, this effect must be considered for pico- or femtosecond lasers.

Note: The specified damage threshold energy density corresponds to 0% damage probability (see ISO 11254). Here, damage means a permanent, laser induced surface modification. Test parameters: angle of incidence: 45°; pulse length (FWHM): see specifications on page 45; beam profile: TEM00; 200 pulses per test site; inspection method: Nomarski dark field microscope (150x).

5.3 Adjustment and Alignment

To ensure optimum performance of the scanning system, it is crucial that the laser beam and the scan head are precisely aligned with respect to each other. Incorrect alignment might lead to the following effects:

- vignetting of the laser beam
- a large, irregular spot
- arbitrary translation of the image field

In most cases, vignetting will be the predominant effect. Vignetting occurs if the laser beam is not able to fully pass through or be reflected by the optical components. Part of the beam’s diameter will be cut off, resulting in power loss and possible system damage due to excessive absorption of laser power.

To avoid significant vignetting, the system must be aligned as precisely as possible, particularly in terms of the beam position relative to the scan head’s optical axis. If the laser beam profile is Gaussian, the maximum tolerances appropriate for most applications are:

- tilt of the laser beam: < 5 mrad
- displacement: < 0.3 mm

If you use a laser with "flat top" beam profile, it can be necessary to align the system with even higher precision. Avoid vignetting especially for a high power laser. Align carefully and – if necessary – reduce the beam diameter to an appropriate value.

Danger!

- Do not stare directly into the laser beam or at any of its deflected radiation. Keep all parts of the body away from direct contact with the laser beam or any of its deflected radiation.
- Adjust the output beam path of the scan head by means of a laser with a laser class not higher than 2. If this is not possible, the laser should be operated at the lowest power. Avoid dangerous deflected radiation!

Caution!

- Remove the protective covers from the scan head's beam entrance and beam exit or objective prior to first-time operation.

In order to achieve optimal processing quality, it may be necessary to fine-tune the working distance A. The working distance A is defined as the distance between the axis of the laser beam entering the scan head and the nominal working plane – see figure 8.

The working distance A can be directly adjusted in small steps. Alternatively, the working distance A can also be adjusted indirectly via the beam divergence – this can be achieved with the help of a beam expander or a variable focusing system (for example, SCANLAB's vario*SCAN* 20) placed in front of the scan head's entrance aperture.

5.4 Checking the Parameters of Application Software

Before you start a laser application, you must carefully check your application software with regard to the maximum allowed scan angle and working area.

If scan angles larger than the *maximum allowed scan angle* indicated on page 45 are used, some vignetting inside the scan head can occur and damage to the interior of the scan head might result. If your application requires larger scan angles and a larger image field, then contact SCANLAB for guidance.

5.5 Safe Start-up and Shutdown Sequences

To assure safety during start-up, proceed exactly as follows:

(1) Start up the air and water cooling facilities and monitor the flow to assure reliable cooling.

(2) Turn on the controller containing the RTC® control board and start up the control software.

(3) Turn on the power supply for the scan head.

(4) Turn on the laser.

When shutting down the system, turn off the components exactly in reverse order.

Caution!

- Before first-time operation, check the polarities of the power supply connections for the scan head.
- Operate the scan head only with appropriate air and water cooling.
- Always turn on the scan head control (controller with RTC® control board and control software) and the power supply for the scan head prior to turning on the laser. Otherwise there is the risk that the laser beam might be deflected in an arbitrary direction.
- Power for the scan head must be applied only when scan head control is active.

6 Optimizing the Application

6.1 Dynamics Configuration (Tuning)

SCANLAB's galvanometer scanners and digital control boards allow precise dynamic control of the two deflection mirrors. This enables exact positioning of the laser beam with high speed.

To reflect differing positioning requirements for various applications, the dynamics configuration (i.e. tuning) of SCANLAB's scan heads can be appropriately optimized. Two widely used types, vector tuning and step tuning, are described in the following sections. SCANLAB can develop special tunings on request.

Optionally, the intelli*SCAN* can be equipped with multiple tunings (and therefore with multiple servo algorithms), thus enabling users to select tunings tailored for their diverse applications. With SCANLAB's RTC®5 board as controller, tuning selection is achieved by issuing a **control_command**. Upon power-up, the scan head selects its first tuning (number 0) by default.

The scan head's factory-supplied tunings, their related dynamics specifications and the corresponding numbers for selection via the **control_command** are listed in "Technical Specifications" on page 45.

Vector Tuning

Many laser applications require the laser focus to trace contours within the working plane at a constant processing speed. To achieve this, the control subdivides the contours into microsteps. Microstep length is determined by the output period and desired speed. Vector tunings are optimized for this kind of vector control.

For optimal scan head operation with vector tuning, observe the following points:

Positioning Speed

For scan heads with vector tuning, it is advisable to also use vectors when positioning with the laser switched off. Compared to hard jumps, a defined positioning speed will prevent excessive oscillation and usually produce shorter positioning times. Positioning speeds can generally be significantly higher than processing speeds.

For the supplied vector tunings, a typical and a maximum positioning speed (in [rad/s]) each is listed in "Technical Specifications" on page 45. There, the typical positioning speed is also specified (for a selected F-Theta objective) as positioning speed within the image field (in [m/s]).

The specified figures are reference values for large vector lengths (typically over 1 mm with a 160 mm F-Theta objective). Select a somewhat lower positioning speed for shorter lengths to avoid possibilities of comparatively high overshoot.

With the SCANLAB RTC® control board, the positioning speed (jump speed) can be set via the **set_jump_speed** software command. The RTC® jump speed (in [bit/s]) is derived by multiplying the positioning speed (in [mm/s]) by the correction file's calibration factor (in [bit/mm]). With vector tuning, the jumps themselves should be executed via the commands **jump_abs** or **jump_rel**.

Processing Speed

The processing speed must be adjusted according to the particular application. As an example, a typical marking speed for marking small characters (marking speed in the image field in [m/s] for a selected F-Theta objective) is specified in "Technical Specifications" on page 45. For other applications or optical configurations, the appropriate processing speed can differ considerably from the specified value.

An appropriate initial value for optimizing the positioning speed is the marking speed listed in "Technical Specifications" on page 45. The process speed (RTC® mark speed) that can be set via an RTC® board is specified by multiplying by the correction file's calibration factor (in [bit/mm]).

Tracking Error (Time Lag)

Galvanometer scanner movements do not occur instantaneously with respect to vector control, but rather after a certain time lag, the tracking error. The tracking error characterizes the reaction properties of the galvanometer scanners and is specified as another key dynamic parameter (see "Technical Specifications" on page 45). The vector control output period must be significantly shorter than the tracking error. Otherwise, instead of moving the galvos with constant speed, the servos would attempt to follow the individual microsteps. This, in turn, would increase power consumption and thermally stress the galvos. SCANLAB therefore recommends as short an output period as possible, no more than 20% of the tracking error. SCANLAB's RTC® boards consistently achieve very good results with an output period of 10 µs.

Oscillation behavior and tracking error must be taken into account by the application software, which synchronizes the scan head and the laser control. If the scan head is controlled via a SCANLAB RTC® control board, then synchronization is easily realized by appropriately setting the scanner and laser delay parameters. SCANLAB recommends the following as initial values for delays:

- Laser-On Delay: 60% of the tracking error
- Laser-Off Delay: 120% of the tracking error
- Jump Delay: 200% of the tracking error
- Mark Delay: 100% of the tracking error
- Polygon Delay: 50% of the tracking error

The RTC® user manual describes how delays can be optimized for an application's quality requirements.

Step Tuning

Some other application types (like boring holes at defined distance intervals) present dynamics requirements that differ substantially from those of vector control. Here, the emphasis is not on constant process speeds, but rather on high jump speeds, because the laser processing is more point-oriented than line or curve dominated. Step tunings are therefore optimized for minimal duration of executed jumps.

To exploit the advantages of this dynamics configuration, the scanners should be controlled to make hard jumps and thus instantaneously move to the target position without microvectorization.

To optimize scan head operation for step tuning, it should also be considered that each jump requires a certain amount of time until the scanners reach the intended positions. This delay time is listed in "Technical Specifications" on page 45 as the step response time for selected jump lengths. The step response time typically scales proportionally with the square root of the jump length. The user can precisely determine the step response behavior by making the scan head perform jumps of varying length, reading the resulting position values via the status channels and subsequently analyzing the data.

With an RTC® board as controller, the jumps should be executed via timed (time-measured) commands (**timed_jump_abs** or **timed_jump_rel**) instead of vector jump commands (**jump_abs** or **jump_rel**). By setting the jump duration to 10 µs, hard jumps at maximum speeds are achieved.

The step response is then considered by interrupting the jump execution for the duration of the corresponding step response time via the **long_delay** command. The jump delay should be set to 0. For point-oriented laser processing, other scanner delays need not be considered and the laser delays can generally be set to 0. The jump rate is then derived from the set delay times and the laser processing time.

For applications requiring high precision, the delay times should not be shorter than the step response time. To minimize total process time, the delay times should be optimized for the corresponding jump lengths.

Process Optimization via Process Simulation

During the testing phase of an application program simulations of the scanning process can be helpful. The scanning process is thereby executed with the laser switched-off and the actual scanned positions are read during execution and compared to the programmed set positions. Many process parameters (as settings for speeds, delays, etc.) can be simply optimized by evaluating such process simulations. In this way simulations can largely replace time-consuming inspection of processed material.

6.2 Optimum Environmental Conditions

Long-term repeatability is very important in many scan head applications, e.g. for rapid prototyping in which the processing operation can span several hours. For such laser applications, the long-term drift and temperature drift of the scan head's galvanometer scanners, which manifest as a shift (offset drift) and increase or decrease in the size (gain drift) of the working image field, can exceed the allowable tolerances.

In such applications, it's helpful to start up the application only after the scanners have reached their operating temperature. In addition, the magnitudes of environmental fluctuations (e.g. operating temperature changes to which the scan head is exposed) should be kept as small as possible and the scan head preferably operated with a constant load.

6.3 Process Monitoring

The scan head provides internal protective mechanisms for monitoring

- the power supply
- the scan range and proper scan operation
- the operating temperature

(also see chapter 2.3, "Internal Protective Functions", on page 13).

In addition, the user has various possibilities for monitoring the scan process as described in the following.

Software Monitoring

When the intelli*SCAN* is operated via an RTC®5 board, then a number of various data signals can be evaluated for monitoring or test purposes.

For applications with critical scan precision requirements, the actual galvo scanner value can be monitored during the entire runtime of an application.

Alternatively, other data signals (e.g. scanner temperature) can be analyzed during normal operation or even when testing user applications.

Malfunctions can be quickly detected if you regularly query (and store) the intelli*SCAN*'s operational states before, after or during operations. Furthermore, determination of a malfunction's cause is simplified considerably (also see chapter 8.1, "Fault Diagnosis and Functional Test", on page 44).

If scan precision is monitored via the PosAck signal of the XY2-100 status word, the intelli*SCAN* also enables changing the PosAck threshold value via the command **control_command**. The default start behavior is for the scan head to set the threshold value to 0.28% of the full position range (i.e. 0.28% of 2^{16} counts) after every power-up or reset. If other threshold values are desired, they must be separately set for each axis.

Optical Process Monitoring

For camera-based observation of the scan head's working field SCANLAB offers a camera adapter. The camera adapter can be mounted between the scan head's beam entrance and the laser flange. Then the camera adapter's dichroitic beam splitter decouples light reflected from the illuminated workpiece and arriving the scan head's beam entrance via the scan objective and the scan mirrors. The light is decoupled from the beam path and then directed to the camera. Please contact SCANLAB for further information (see page 42).

6.4 Configuring the Effective Calibration

The servo electronic of the intelli*SCAN* can be configured to scale the position values received from an RTC®5 board by a specific factor (1, 1/2, 1/4 or 1/8). The position signals (optionally) returned by the scan systems to the RTC®5 remain unaffected, as do the pre-configured calibrations of SCANLAB's scan systems. However, the effective calibration can be thereby reduced to confine the scan area to a smaller angular range – with a higher angular resolution.

The default start behavior is for the scan system to start with a scale factor of 1 (i.e. with SCANLAB's pre-configured calibration) upon power-up or after a reset. The pre-configured calibration value is specified in the technical specifications on page 45.

6.5 Configuring the Start Behavior

In its default configuration the intelli*SCAN* is pre-configured by SCANLAB so that

- the scan head transmits a status word compliant with the XY2-100 protocol on all receive channels (also see section "Returned Signals" on page 9),
- the first tuning (number 0) is selected (also see chapter 6.1, "Dynamics Configuration (Tuning)", on page 35),
- a PosAcknowledge threshold value of 0.28% of the full position range (i.e. 0.28% of 2^{16} counts) is set (also see chapter 6.3, "Process Monitoring", on page 38),
- a scale factor of 1 is set (also see chapter 6.4, "Configuring the Effective Calibration", on page 39).

The settings can be changed via the **control_command**. The changed settings are only temporary, however they can be additionally saved as starting settings for subsequent power-ups or resets (power supply switched off and switched on) via the **control_command**.

As long as the start behavior is not changed as described, the scan head starts with the starting settings pre-configured by SCANLAB on every power-up or reset.

7 Routine Maintenance and Customer Service

7.1 Routine Maintenance of the Optical Surfaces

Dirty objectives and mirrors increase the absorption of laser power by their respective optical surfaces. Dirt, dust and other contaminants can distort the laser beam, burn into the surface and damage the optical elements. The warranty does not cover any damage due to improper use, cleaning or handling.

Danger!

- Never stare at the laser beam or its deflected radiation when performing routine maintenance of the scan head. Keep all parts of the body away from direct laser beams or deflected radiation. When the laser beam is not required, turn it off or reliably block it via a shutter to prevent its entry into the scan head.

Routine Maintenance of the Mirrors

The deflection mirrors are especially sensitive components and should not be touched or removed from the scan head. Nevertheless, you must regularly inspect the mirrors for dirt, dust and other contaminants. The mirrors must also be inspected after a long storage time.

If inspection reveals dust particles, then remove them by blowing air on the mirror's surface with the help of a rubber squeeze bulb or a source of compressed clean air.

If the dust cannot be removed in this manner, or if inspection reveals more serious contamination, then contact SCANLAB for guidance. In extreme cases, the complete scan head must be returned to SCANLAB for inspection and cleaning of the mirrors. However, in some situations SCANLAB might be able to recommend a user-performed special cleaning procedure.

Caution!

- Improper cleaning procedures – for instance cleaning cleaning metal-coated mirrors with acetone – can cause irreparable damages to the mirror coatings. Therefore, if the abovementioned cleaning procedure (with air) is insufficient, always contact SCANLAB for guidance before you start to perform any further cleaning procedures yourself.

Routine Maintenance of the Objective's Optical Surface

The outermost optical surface of the scan head's objective is cleanable by the user. Regularly check the scan head's objective.

If dirt, dust or other contaminants are found, clean the objective's optical surface as follows: Using a rubber squeeze bulb or compressed clean air, blow air on the objective's surface to remove dust and dirt particles. If the objective is still not clean, then use solvent and lens cleaning tissues as described below:

(1) Create a lens-tissue brush by folding a clean lens tissue so that the fold is about half as wide as the objective's lens surface.

(2) Dampen the lens-tissue brush with solvent. Don't use too much solvent, because otherwise drying marks might appear.

(3) Carefully grip one end of the dampened lens-tissue brush without touching any part of the tissue that will touch the lens surface.

(4) Place the dampened lens-tissue brush in the center of the objective's lens surface. Then use a *circular* motion to wipe slowly but steadily from the center of the optic around to the outer edges.

Repeat the above procedure until the objective's optical surface is completely clean. For each cleaning swipe, create a new lens-tissue brush.

Cleaning Notes

- Avoid skin contact with the optic.
- Use only clean lint-free tissues specially manufactured for cleaning optics (e.g. "Kodak lens cleaning paper"). Always use lens tissues with a solvent, because dry tissue can scratch optical surfaces.
- Use a solvent such as acetone or isopropanol of high purity (evaporation residue < 0.001%). Read and follow the safety advice and warnings for the solvents you will be using.
- Use clean gloves or finger cots that are impermeable to the organic cleaning solvents you will be using.
- Always wipe slowly but steadily, using a circular motion from the center of the optic around to the outer edges. Do not rub back and forth!
- Only wipe with slight pressure!

7.2 Customer Service

Servicing and Repairs

Except for routine maintenance of the optical surfaces, the scan head does not contain user-serviceable internal parts. All servicing and repairs should be performed only at SCANLAB. Only SCANLAB has the proper test facilities and procedures to service, repair and calibrate the system optimally.

Product Warranty

SCANLAB guarantees this product to be free of defects in manufacturing and material. The warranty is valid for 12 months after delivery. Repairs covered under the warranty will be performed at SCANLAB.

The scope of the warranty is limited to repair or replacement of the SCANLAB product.

SCANLAB is responsible for the return delivery of products repaired under warranty; the customer is responsible for delivery to SCANLAB.

SCANLAB will not be held responsible:

- when the product has been damaged through misuse or improper operation
- for damage due to improper laser power (e.g. focused beam on optical surfaces) or improper adjustment
- for damage to optical components (mirrors, objective, etc.) caused by improper handling or cleaning
- for consequential damages
- if the scan head has been altered
- if the warranty seal on the scan head's housing has been broken

If a returned scan head must first be brought into a serviceable state by SCANLAB (e.g. by removing alignment pins and other customer-added parts or cleaning the scan head) before servicing can begin, then the customer must bear the additional cost.

Contacting SCANLAB

For service, repairs, advice or information, simply contact SCANLAB using one of the contact possibilities listed below:

SCANLAB GmbH
Siemensstr. 2a
82178 Puchheim
Germany

Tel. +49 (89) 800 746-0
Fax: +49 (89) 800 746-199

info@scanlab.de
www.scanlab.de

Product Disposal

The intelli*SCAN* 20 can be returned to SCANLAB for a fee to be properly disposed of in compliance with environmental regulations.

8 Troubleshooting

If problems occur while operating this device, verify that all operating instructions have been adhered to and then carry out the following troubleshooting procedures:

Problem	Possible Cause	Remedy
Low laser power	Dirty objective	Clean as described in "Routine Maintenance of the Optical Surfaces" on page 40
	Altered controller software parameters	Check input parameters
	Dirty or damaged mirror	Check mirrors. If they are contaminated, call SCANLAB for guidance. Return damaged scan head mirrors for repair.
Changed laser spot	Dirty or damaged objective	Clean as described in "Routine Maintenance of the Optical Surfaces" on page 40
	Dirty or damaged mirror	Check mirrors. If they are contaminated, call SCANLAB for guidance. Return damaged scan head mirrors for repair.
	Laser out of adjustment	Adjust laser
No laser beam	Problem with the laser	Check laser and electrical connections
	Problem with the laser controller	If the RTC® board is used, check all electrical connections and the power supply
	Laser beam path blocked or shutter closed	Check laser beam path
Scan head does not steer laser beam in one or both directions	Problem with the scan head controller	Check power and data cables. Check software commands. Switch off scan head, and then restart.
Scan head stopped responding	The scan head's electronics have disconnected the scan head from the power supply due to impermissible supply voltages (see page 13)	Ensure correct supply voltages, switch off scan head, and then restart

If the problems persist, please send the scan head to customer service.

8.1 Fault Diagnosis and Functional Test

If a problem occurs, the intelli*SCAN*'s versatile status return functions can be used for scan head diagnosis, too. These functions allow to read for instance

- the current operating state
- the operating state at the moment of the most recently occurred operation interruption and
- an event code, indicating which particular event caused the scan head to enter a temporary or permanent error state.

Also see section "Returned Signals" on page 9.

In general, all status informations can even be read after the scan head has entered a temporary or permanent error state due to an internal protective mechanism (provided that the scan head is still sufficiently powered).

To verify that data transfer capability between the RTC®5 and the scan head is intact, an 8-bit value – separately for each axis – can transmitted to the scan head via the command **control_command**. Subsequently, a 16-bit value will be returned on the corresponding status channel: If data transfer is error-free, then the upper 8 bits of the returned 16-bit value will be identical with the originally sent 8-bit value, and the lower 8 bits will be identical with the complement of the sent 8-bit value.

These 16-bit values will be returned until the **control_command** is used to select another return data type.

To facilitate – after a data transfer verification – restoration of the status return behavior in effect prior to the data transfer verification, the **control_command** allows the prior data type to be temporarily stored for later retrieval.

9 intelli*SCAN* 20 Technical Specifications

(all angle specifications optical)

SCANLAB ID number

of scan head	148850

Aperture

maximum diameter of the laser beam inside the scan head	20 mm

Control

Input and Output Signals	SL2-100
Maximum range for control values (1)	–524288 to +524287
Calibration	±0.408 rad with ±503316 bit
Maximum allowed scan angle (vignetting insignificant) (2)	
- without objective	±0.41 rad

Power supply

Requirements	30 V DC (29 - 33 V), max. 6 A or ±(15+1.5) V DC, max. 6 A each pole

Optical Performance

Gain error	< 5 mrad
Zero offset	< 5 mrad
Nonlinearity	< 3.5 mrad
Repeatability	< 2 µrad
Long-term drift over 8 hours (after warm-up)	< 0.6 mrad

Tuning Specifications (Dynamic Performance) (3)

... for tuning 113719

Selection number	0
Tracking error	< 0.32 ms
Dither (RMS)	< 5.0 µrad
Typical positioning speed (* with 160 mm objective)	70 rad/s (* 11.2 m/s)
Maximum positioning speed	100 rad/s
Typical marking speed (for marking small characters, with objective)	1.0 m/s
Step response (settling to 1/1000 full scale)	
• 1% of full scale	< 0.70 ms
• 10% of full scale	< 1.90 ms

Cooling Specifications

rate of air flow	20 l/min (Δp<2 bar)
rate of water flow	5 l/min (Δp<0.1 bar, p<4 bar)

Mirror

Coating	dielectrical high performance coating
Working wavelength	1064 nm
Reflectivity	
– at 1064 nm	more than 99.5% per mirror, over the full range of angles
– at 630 nm to 670 nm	more than 70% per mirror
Maximum allowed average laser power (* with specified cooling)	1000 W (2000 W *)
Maximum allowed laser power density continuous wave (* with specified cooling)	1000 W/cm^2 (2000 W/cm^2 *)
Damage threshold for pulsed operation (with specified working wavelength, pulse length 10 ns, 200 on 1, also see page 33)	5 J/cm^2

(1) This maximum range for input values should be regarded as a theoretical range. Due to the danger of vignetting by the mirrors (also see page 6), the specified maximum scan angle must never be exceeded.
(2) Theoretical value (see page 6 and page 7)
(3) See page 35.

Weight

without objective	5.8 kg

Operating and Storage Conditions

Operating temperature	25 °C ± 10 °C
Storage temperature	−35 °C to +60 °C

For storage, make sure to remove all water from the device's water-cooled parts.

Environmental conditions	non-condensing, non-corrosive

9.1 Electromagnetic Compatibility

Compliance with EC Guidelines for Electromagnetic Compatibility (EMC)

The intelli*SCAN* and intelli*DRILL* series of scan heads has been determined to be in compliance with EC-Guidelines 89/336/EEC (electromagnetic compatibility).

For that purpose, a scan head from the above-mentioned series was tested in the following configuration:

- intelli*SCAN* 10, digital
- RTC®4 PC interface board

Test Specifications

Evidence of fulfillment of the protection goals of the July 1993 version of EC Guidelines 89/336/EEC (CE Conformity for EMC) based on

- EN 61000-6-2: 2005
- EN 61000-6-4: 2007

Result

The device under test fulfills the specifications.