PICOSCALE

USER MANUAL

SmarAct
PERFECT MOTION

SmarAct
PERFECT MOTION

The information given in this document was carefully checked by our team and is constantly up-dated. Nevertheless, it is not possible to fully exclude the presence of errors. In order to always get the latest information, please contact our technical sales team.

Document Version: 2.1.4

TABLE OF CONTENTS

1 *INTRODUCTION*

Congratulations on your purchase of the SmarAct **PICO**SCALE interferometer! You have acquired a powerful tool for displacement measurements with picometer resolution. We are convinced that the innovative features will make working with the **PICO**SCALE a pleasant and remarkable experience.

1.1 Preface

This manual contains user information for the SmarAct **PICO**SCALE system, which includes a control box, various sensor heads, a Breakout-Box and an Environmental Module.

> **NOTICE**
> Read this manual carefully before operating the **PICO**SCALE for the first time. Special attention should be given to the material in chapter 2 "Product Safety", which describes the secure handling of the **PICO**SCALE system.

1.2 Technical support

Should you experience any difficulties with your **PICO**SCALE system or need any technical information, please visit our web site: *www.picoscale.com*. Additional support can be obtained by contacting our technical support at *PicoScaleSupport@smaract.com* or by phone at *+49 441 800 879 0*. When communicating with our Technical Support, the Support Engineer responding to your request will require the model and the serial number.

1.3 Signal words and symbols in this manual

This manual may contain sections in which particular hazards are defined or special attention is drawn to particular conditions. These sections are indicated with signal words according to ANSI Z-535.6 and safety symbols (pictorial hazard alerts) in accordance with ANSI Z-535.3 and ISO 7010.

1.3.1 Signal words

Four signal words are used in this documentation: **DANGER**, **WARNING**, **CAUTION** and **NOTICE**.

The signal words **DANGER**, **WARNING** and **CAUTION** designate the degree or level of hazard when there is a risk of **injury**:

> ## DANGER
> Indicates a hazardous situation that, if not avoided, **will** result in **death** or **serious injury**. Do not proceed beyond a **DANGER** notice until the indicated conditions are fully understood and met. This signal word is to be limited to the most extreme situations.

> ## WARNING
> Indicates a hazardous situation that, if not avoided, **could** result in **death** or **serious injury**. Do not proceed beyond a **WARNING** notice until the indicated conditions are fully understood and met.

> ## CAUTION
> Indicates a hazardous situation that, if not avoided, **could** result in **minor** or **moderate injury**. Do not proceed beyond a **CAUTION** notice until the indicated conditions are fully understood and met.

The signal word **NOTICE** is used when there is a risk of **property damage**:

> ## NOTICE
> Indicates information considered important, but not hazard-related.

Messages relating to hazards that could result in both personal injury and property damage are considered safety messages and not property damage messages.

1.3.2 Symbols

The signal words **DANGER**, **WARNING** and **CAUTION** are always emphasized with a safety symbol that indicated a special hazard, regardless of the hazard level:

This symbol is intended to alert the operator to the presence of important operating and maintenance instructions.

This symbol is intended to alert the operator to the danger of exposure to hazardous visible and invisible laser radiation.

This symbol is intended to alert the operator to the presence of dangerous voltages within the product enclosure that may be of sufficient magnitude to constitute a risk of electrical shock.

2 *PRODUCT SAFETY*

2.1 Optical safety

Because of its special properties, laser light poses safety hazards not associated with light from conventional sources. The safe use of the lasers require that all laser users, and everyone near the laser system, are aware of the danger involved. The safe use of the laser depends upon the user being familiar with the instrument and the properties of coherent, intense beams of light.

> **CAUTION**
> The **PICO**SCALE Controller contains an infrared diode laser with an output of less than 0.2 mW at 1520 nm - 1580 nm (less than 0.3 mW for V1.4 and less than 0.6 mW for V1.4-HP) and red diode laser with an output power of less than 0.6 mW at 650 nm (no red laser for V1.4-HP).
>
> Although the PicoScale is a Class I product due to the low output power, it is a good practice not to stare directly into the laser beam. Never use optical instruments to observe the beam, this can cause serious eye damage.
>
> Always use the PicoScale as intended by this manual!

2.2 Electrical safety

The SmarAct **PICO**SCALE controller contains hazardous voltages. Do not disassemble the enclosure. There are no user-serviceable components inside. All units are designed to operate as assembled. Warranty will be voided if the enclosure is disassembled.

> **WARNING**
> **High voltage inside.** To avoid electrical shock before powering the unit, make sure that the protective conductor of the 3-conductor power cord is correctly connected to the protective earth contact of the socket outlet. Improper grounding can cause electric shock resulting in severe injury or even death.

> **WARNING**
> **Shock warning.** Do not operate without cover installed. Do not stick any material through the ventilation holes. Do not operate under wet/damp conditions.

> **WARNING**
> **Observe all terminal ratings.** To avoid damage, fire or shock hazard, observe all ratings marked on the PicoScale Controller or documented in the manual.

> **NOTICE**
> High electrostatic charges readily accumulate in the human body and equipment and can easily discharge without detection. Although the electronics features have impressive input protection, permanent damage may occur on devices subjected to high-energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation.
> The most common ESD damage occurs while handling the device during installation or use. Take the necessary measures to protect the system from ESD, e.g. by wearing a wrist strap.
> Dry air and carpet can create an even higher potential for ESD. Precautions or shielding need to be taken for demonstrations or trade show exhibitions.

2.3 Safety precautions

> **NOTICE**
> **End of life handling.** The equipment contains substances that could be harmful to the environment or human health. In order to avoid release of such substances into the environment, we encourage you to recycle this product in an appropriate system that will ensure that most of the materials are reused or recycled appropriately. Please contact your local authorities for disposal or recycling information.

> **NOTICE**
> **Provide proper ventilation.** In order to prevent overheat events, system failure and damage the ventilation holes of the PicoScale Controller must **not** be covered. Do not stack several **PICO**SCALE Controllers.

> **NOTICE**
> **Always clean fiber prior connection!** Prior to connecting an interferometer head, make sure to clean both the fiber connector and the fiber receptacle with suitable fiber cleaners. This is necessary to achieve the optimal signal quality and avoid permanent damage to the fiber end surfaces.
> For further information, please refer to the information presented in section 6.3.

> **NOTICE**
> **Handle with care!** The sensor heads and the optical fibers are small high-precision parts and subject to damage under rough handling. Please make sure to treat the fibers carefully and do not bend them too tightly; the minimum bending radius of 30 mm should always be respected. Be sure that the interferometer heads are not torn or sheared off the fibers. The **PICO**SCALE control system contains sensitive optics and electronics. Make sure to use the original PicoScale case for transport.

2.4 Compliance

The **PICO**SCALE laser interferometer and its accessory products have been certified in cooperation with an independent testing lab to be in compliance with the environmental and safety directives listed in the following chapters.

2.4.1 CDRH/EN60825-1

The **PICO**SCALE laser interferometer system complies with all of the requirements of EN60825-1. It further complies with 21 CFR 1040.10 except for deviations pursuant to Laser Notice No. 50, dated June 24, 2007.

The following table lists **PICO**SCALE part or model numbers, and their corresponding CDRH accession numbers.

Table 2.1: **PICO**SCALE CDRH Accession Numbers

Part/Model number	Accession Number	Part/Model number	Accession Number
PS-CTRL-V1.1-TAB (*)	1711061-000	PS-CTRL-V1.3-RACK (*)	1711061-000
PS-CTRL-V1.2-TAB (*)	1711061-000	PS-CTRL-V1.4-RACK	1711252-000
PS-CTRL-V1.3-TAB (*)	1711061-000	PS-CTRL-V1.4-TAB-HP	1810594-000
PS-CTRL-V1.4-TAB	1711252-000	PS-CTRL-V1.4-RACK-HP	1810594-000

(*) Discontinued

2.4.2 Low voltage directive

The **PICO**SCALE laser interferometer complies with the basic requirements of the **Low Voltage Directive 2014/35/EU**.

Compliance with this directive has been verified by application of the following harmonized standards:

- **EN 61010-1:2010**:
  Safety Requirements - Part 1: General requirements

- **EN 60825-1:2014**:
  Safety of laser products - Part 1: Equipment classification and requirements (compare 2.4.1)

2.4.3 EMC directive

The **PICO**SCALE laser interferometer complies with the basic requirements of the **EMC Directive 2014/30/EU**.

Compliance with this directive has been verified by application of the following harmonized standards:

- **EN 61326-1:2013**:
  EMC requirements - Part 1: General requirements

- **EN 55011:2011**:
  Radio-frequency disturbance characteristics - Limits and methods of measurement

According to EN 61326-1:2013 the following test specifications have been used:

- **EN 61000-4-2:2009** - Electrostatic discharge immunity test

- **EN 61000-4-3:2010** - Radiated, radio-frequency, electromagnetic field immunity test

- **EN 61000-4-4:2010** - Electrical fast transient/burst immunity test

- **EN 61000-4-5:2006** - Surge immunity test

- **EN 61000-4-11:2004** - Voltage dips, short interruptions and voltage variations immunity tests

2.4.4 RoHS directive

The **PICO**SCALE laser interferometer complies with the basic requirements of the **RoHS Directive 2011/65/EU**.

Compliance with this directive has been verified by application of the following harmonized standards:

- **EN 50581:2012**:
  Technical documentation with respect to the restriction of hazardous substances

2.4.5 Declaration of Conformity

Declaration of Conformity

according to DIN EN ISO/IEC 17050-1:2010

Manufacturer: SmarAct GmbH
Manufacturer's Address: Schütte-Lanz-Strasse 9
                                 26135 Oldenburg, Germany

The manufacturer hereby declares that the product and its related accessory

Product Name: PicoScale
Model Numbers: PS-CTRL-V1.1-TAB, PS-CTRL-V1.2-TAB, PS-CTRL-V1.3-TAB,
                                 PS-CTRL-V1.4-TAB, PS-CTRL-V1.3-RACK, PS-CTRL-V1.4-RACK
Product Options: all

complies with the following European directives:

2014/35/EU: **Low Voltage Directive**
2014/30/EU: **EMC Directive**
2011/65/EU: **RoHS Directive**

The applied standards certifying the conformity are listed below:

Electromagnetic Emission: **DIN EN 61326-1:2013**
                                 DIN EN 55011:2011, Groupe 1, Class B [1]
Electromagnetic Immunity: **DIN EN 61000-4-2:2009**/DIN EN 61326-1:2013 (DIN EN 61000-6-2)
                                 DIN EN 61000-4-3:2010/DIN EN 61326-1:2013 (DIN EN 61000-6-1)
                                 DIN EN 61000-4-4:2010/DIN EN 61326-1:2013 (DIN EN 61000-6-2)
                                 DIN EN 61000-4-5:2006/DIN EN 61326-1:2013 (DIN EN 61000-6-2)
                                 DIN EN 61000-4-11:2004/DIN EN 61326-1:2013 (DIN EN 61000-6-2)
Safety (Low Voltage Directive): **EN 61010-1:2001**
Environmental Affairs: **EN 50581:2012**

Articles manufactured on or after the Date of Issue of the Declaration of Confirmity do not contain any of the restricted substances in concentrations/applications not permitted by the RoHS Directive.

July 25, 2016
Oldenburg, Germany

Axel Kortschack
Managing Director

---

[1]with active PS-BOB-V1.0-TAB the emission Class is A

2.5 Intended use

The **PICO**SCALE Controller is intended to be used in indoor locations with constant temperatures inside the specified range (see table 2.2). Temperature fluctuations can have influence on laser stability and measurement results and should be kept small (e.g., avoid exposure to direct sunlight).

Table 2.2: Operation conditions for **PICO**SCALE Controller

	General Conditions
Power supply	90-246 V_{AC} @ 47-63 Hz
Input current	0.5 A_{RMS} @ 230 V_{AC}
Environment	Pollution degree 2; Indoor location
Environmental temperature	15 °C - 30 °C
Environmental humidity	5% to 80% RH, non-condensing
Storage temperature	0 °C - 50 °C

2.6 Unpacking

Before unpacking the **PICO**SCALE Controller please refer to chapter 6 of this manual.

2.7 Disposal of old equipment

According to the EU directive 2012/19/EU, as of August, 13, 2012, electrical and electronic equipment may not be disposed in the member states of the European Union with other waste.

SmarAct GmbH respects the manufacturer's product responsibility and will take care of environmentally correct disposal of old SmarAct products free of charge. To dispose old SmarAct equipment, you can return it to SmarAct to the following address postage-free:
SmarAct GmbH
Schütte-Lanz-Strasse 9
26135 Oldenburg, Germany

WEEE-Reg.-Nr.: DE 47992153

3 PICOSCALE *FUNDAMENTALS*

The **PICO**SCALE is a powerful system for optical and non-invasive displacement and vibration measurements. The three channel system is based on a miniaturized Michelson interferometer. The system features powerful interfaces and flexible software modules. Due to useful accessories the system can be adapted to specific needs. The **PICO**SCALE GUI allows to operate the system out of the box. In summary, these versatile characteristics make the **PICO**SCALE a very powerful tool for every lab!

3.1 General setup and basic components

Each **PICO**SCALE measurement setup requires a few basic components. The **PICO**SCALE controller is the core component. In the controller, coherent light is generated by a laser diode. A fiber network distributes the laser light into three output channels.
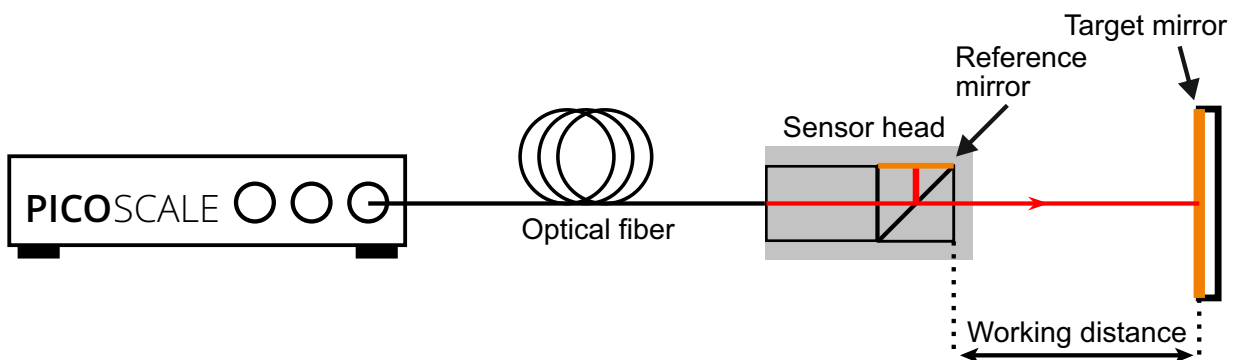
Figure 3.1: Basic setup of a **PICO**SCALE displacement measurement. Miniaturized sensor heads are connected to the **PICO**SCALE controller via optical fibers. The system measures the displacements of a target mirror relative to the sensor head.

Up to three sensor heads can be connected to the controller via optical FC/APC-terminated fibers. Within the sensor head, the laser light is divided into a reference and a measurement beam by a beam splitter, being the central component of a Michelson interferometer. In standard sensor heads one side of the miniaturized beam splitter cube is coated with a reflective coating, which acts as reference mirror. The measurement beam exits the head and is reflected by the measurement target, which can be a mirror, a piece of glass or almost any other technological relevant surface. Both, the reflected reference and measurement beam interfere in the center of the beam splitter cube and the combined light is guided back to the controller. Due to advanced signal processing methods, based on lock-in detection and fast FPGA based evaluation algorithms, the **PICO**SCALE is able to measure target mirror displacements with single picometer resolution and sample rates of up to 10 MHz.

3.2 Measurement principle

3.2.1 Michelson interferometer

The **PICO**SCALE displacement sensor is based on a Michelson interferometer with an extremely compact and stable reference arm.
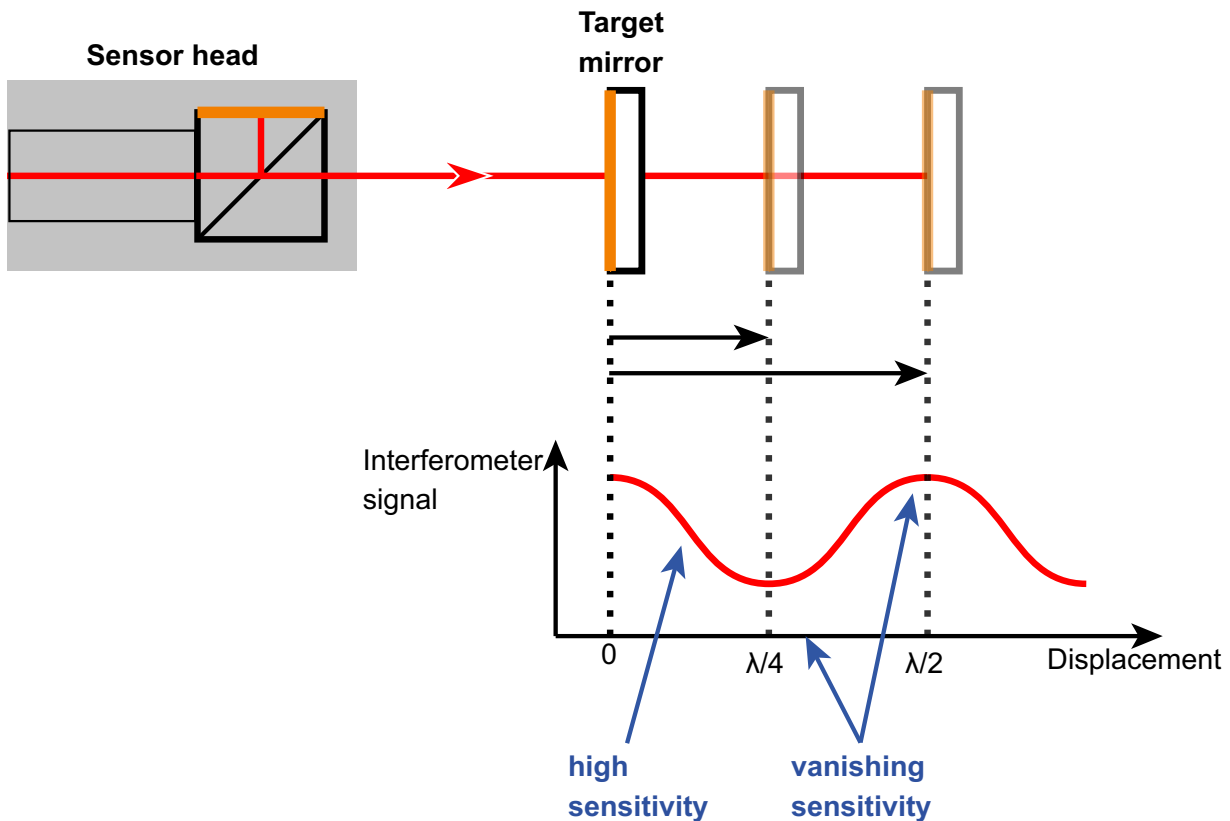

Figure 3.2: Measurement principle of a Michelson interferometer. Constructive and destructive interference occur due to a displacement of the target mirror. To circumvent these *blind spots* the **PICO**SCALE utilizes sinusoidal phase modulation, see section 3.2.2.

The interferometer is driven by a laser, which is a coherent light source, that is required if a Michelson interferometer is operated with (very) unequal arm lengths as it is the case for the **PICO**SCALE. At a beam splitter, the light is divided into two parts. One part is reflected at a fixed reference mirror and guided back to the beam splitter. The other part of the light hits the target mirror. This light is also reflected while picking up a relative phase with respect to the reference beam. Inside the beam splitter, both reflected beams interfere and the coherent superposition is recorded by a photo detector.

In the **PICO**SCALE system, the beam splitter is located in the sensor head, whereas the light source, a stabilized, distributed-feedback (DFB) laser diode and the photo detector are located in the controller housing. The wavelength of the laser is around 1550 nm. Inside the controller, a fiber network distributes the laser light to three independent measurement channels. The output power of each channel is around 150 µW.

The integration of the miniaturized beam splitter into the sensor head ensures that changes in the fiber length, possibly caused by temperature gradients, do not affect the measurement.

In a Michelson interferometer, two light beams interfere with each other. Due to path length differences in the measurement and the reference arm of the interferometer, constructive and destructive interference occur. In case of constructive interference, the recorded interferometer signal is high, while at destructive interference the recorded signal is low. A displacement of the target mirror causes a change in the relative optical path lengths and thus in the phase difference of target and reference beam, compare figure 3.2. As a result, the intensity measured by the photo diode is changed. This intensity change in turn is used to infer positions and displacements with high accuracy.

In standard interferometry, the interference signal is sinusoidally dependent on the phase difference between the reference and probe beam. This phase difference depends on the target mirror position. Thus, during constant movement, the resulting intensity signal is a sinusoid, similar to the signal shown in figure 3.2. Due to the symmetry of the sinusoid, it is not possible to determine the movement direction at every working point. Furthermore, the sensitivity (change in signal intensity due to change in target position) is not constant during movement. Thus, for long range and high-resolution position measurements, the *standard* Michelson interferometry is not ideally suited.

The **PICO**SCALE uses *sinusoidal phase modulation* of the laser beam to overcome these disadvantages and provides high accuracy and resolution of position measurements as well as information on the direction of the moving object mirror!

3.2.2 Sinusoidal phase modulation
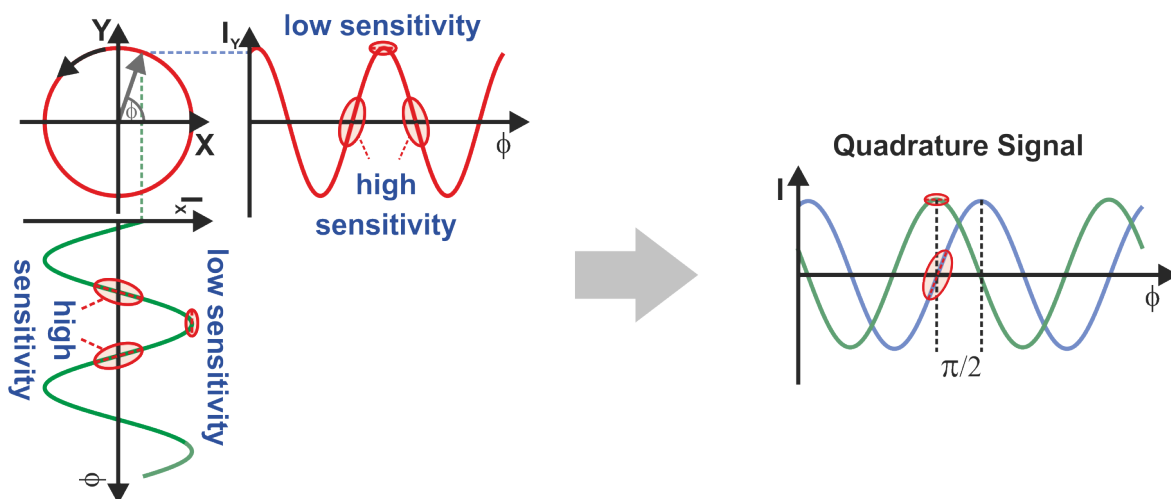
Figure 3.3: Quadrature signal detection: points of low sensitivity in one signal are compensated by high sensitivity in the quadrature signal.

Thus, sinusoidally modulating the wavelength of the laser light can overcome the aforementioned disadvantages. This wavelength modulation is initiated by modulating the injection current of the used distributed feedback (DFB) laser diode. The modulation of the wavelength produces a sinusoidally phase modulated (SPM) interference signal. Due to appropriate demodulation, it

becomes possible to extract the quadrature signal, which is a two dimensional signal, dependent on the target mirror position, depicted in figure 3.3. The two extracted sinusoidal signals are phase-shifted by 90 degrees and thus are in quadrature. The X and Y components are shown in figure 3.3, left. Constant movement of the target mirror produces a circle in a two dimensional representation. The right part of the figure shows both signal components simultaneously and it can be seen that any blind spot in one signal is compensated by a high sensitivity point in the other. Thus, the sensitivity is maintained high during movement.

Furthermore, the phase relationship between the two components allows to unambiguously infer the movement direction. While an increasing relative position of the target mirror leads to a counter-clockwise rotation of the X-Y vector, a decreasing position leads to a clockwise rotation. Thus, sinusoidal phase modulation interferometry is perfectly suited for high-resolution, long-range position measurements.

3.2.3 Working range

During the initial adjustment phase it is required to define a so-called working range. This is the region where the target mirror is expected to be during the measurement. The setting of the working range is mapped to internally stored configuration values and an appropriate setting subsequently leads to highest accuracy and performance of the **PICO**SCALE position measurements.

3.3 Traceability

Although the DFB laser has a very high spectral purity, spectral width below 10 pm, the emitted wavelength is not constant due to unavoidable thermal drifts. Since the measured target position is directly dependent on the emitted wavelength, a feedback system stabilizing the wavelength of the DFB laser is mandatory. In order to stabilize the temperature of the laser diode, it is equipped with a thermo-electric cooler (TEC). Besides stabilizing the temperature, the TEC element can be used to actively control and tune the temperature and thus the emitted wavelength. The wavelength is locked to an absorption line of a gas absorption cell, according to the standards NIST SRM 2517a or SRM 2519a. This reference cell is filled either with acetylene or hydrogen cyanide and allows to determine the wavelength of the laser within a range of lower than ± 1 pm. The gas absorption cells are extremely insensitive to environmental parameters like temperature, humidity, pressure and also on electro-magnetic fields. Thus, these cells offer a persistent and reliable wavelength standard to stabilize the wavelength of the DFB laser diode.

The gas absorption cell is integrated in the **PICO**SCALE controller housing. One part of the modulated laser light is guided through the reference cell and the transmitted signal is recorded and evaluated. A feedback loop controls the laser chip temperature such that the wavelength is continuously kept at an absorption line.

3.4 Environmental compensation

When the interferometer is used in a vacuum environment, no environmental compensation is necessary. When the interferometer system is operated in ambient conditions, variations in the

refractive index of the air can significantly influence interferometric position measurements. The refractive index of air may change due to fluctuations in temperature, pressure and humidity (TPH). If the refractive index increases, the *optical* path length of the laser light increases proportionally. This effect would pretend a movement of the object mirror even if the *geometrical* path did not change. To compensate a variation of the refractive index, it is necessary to measure the atmospheric conditions such as air temperature, pressure and humidity. Based on these values, the National Institute of Standards and Technology (NIST) suggests a formalism based on a set of modified Edlén equations to calculate the refractive index of air[1]. The **PICO**SCALE follows the suggested formalism to calculate the refractive index and thus to correct the position data.

3.4.1 Dead path

The dead path is the distance between the absolute and relative zero position of the **PICO**SCALE system. As figure 3.4 highlights, the absolute zero position is at the surface of the beam splitter cube. The relative zero position can be defined freely. The system measures any position change

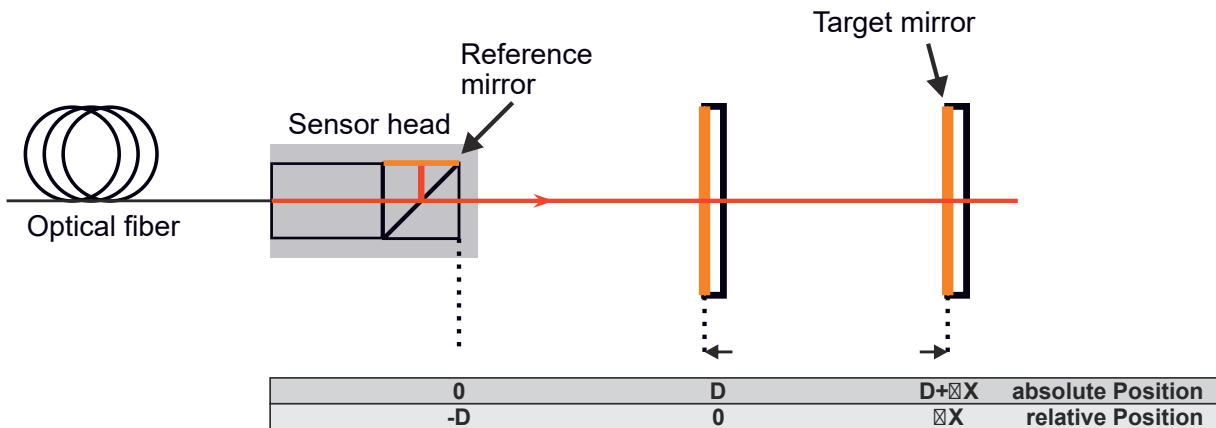| | 0 | D | D+□X | absolute Position |
| | -D | 0 | □X | relative Position |

Figure 3.4: The dead path is the distance between the absolute zero position, at the front face of the beam splitter cube and the freely defined relative zero position.

relative to this internal zero position. When the measurement is done in ambient environment, the changes in the refractive index cause a measurable change in the **PICO**SCALE position signal. Based on the recorded environmental parameters the system calculates a correction factor to compensate this virtual drift. The **PICO**SCALE measures the absolute distance between sensor head and target mirror during the initial adjustment phase. When the absolute measurement is done, the controller automatically zeros the internal position value, such that the measured absolute distance is equal to the dead path. The measured dead path is stored automatically in the system and can be accessed with appropriate properties. Furthermore, each time the internal position value is set, the dead path is updated automatically, if the environmental compensation is active.

---

[1]`http://emtoolbox.nist.gov/Wavelength/Documentation.asp#EdlenorCiddor`

4 *BASIC CONCEPTS*

4.1 Modular architecture

The **PICO**SCALE is set up in a modular architecture to allow for highest possible flexibility, understandability and efficient maintenance. Each module has inputs and/or outputs that can be configured by the user. The inputs may be outputs from other modules while the outputs can either be directly linked to interfaces like the **PICO**SCALE Breakout-Box (BOB) or set up as input for subsequent modules. This very open architecture allows you to set up sophisticated networks. The **PICO**SCALE modules and their possible dependencies are depicted in figure 4.1. The functionality of the modules can be summarized as follows.

4.1.1 Advanced trigger

The Advanced Trigger module is a versatile tool that allows control of a variety of other modules. Within this module, triggers can be configured that can be used as start or stop events for other modules (Clock Generator, Counters, Signal Generator, Stream Generator) or they can be directly displayed through the GPIO interface. Several data sources can be used within the Advanced Trigger module to configure the respective events. Beyond others, position data, data increments or external data (through the GPIO interface) can be used to configure trigger sources. Furthermore, trigger sources can be linked with logical operations to allow for sophisticated trigger configurations. A detailed description of the Advanced Trigger functions can be found in section 7.3.

4.1.2 Stream generator

The data transfer between the **PICO**SCALE controller and the user PC is called streaming. A sophisticated aggregation, compression and decompression protocol ensures highest possible data rate of up to 480 Mbit/s so that position data, which is a 48 bit data source, can transferred with a 10 MHz rate.

The Stream Generator is the fundamental software module that handles **PICO**SCALE data sources. Within this module you can configure the data stream to your PC (USB or Ethernet) and set up the appropriate data rate as well as appropriate digital low-pass filters to avoid aliasing or unnecessary oversampling. The Stream Generator is connected to the trigger module so that triggered data streaming can be set up. All functions of the stream generator can be conveniently be accessed via the **PICO**SCALE GUI. For example, start and stop trigger events can be chosen and the number of frames to be acquired can be defined. Details on the Stream Generator configuration can be found in section 7.6.4.
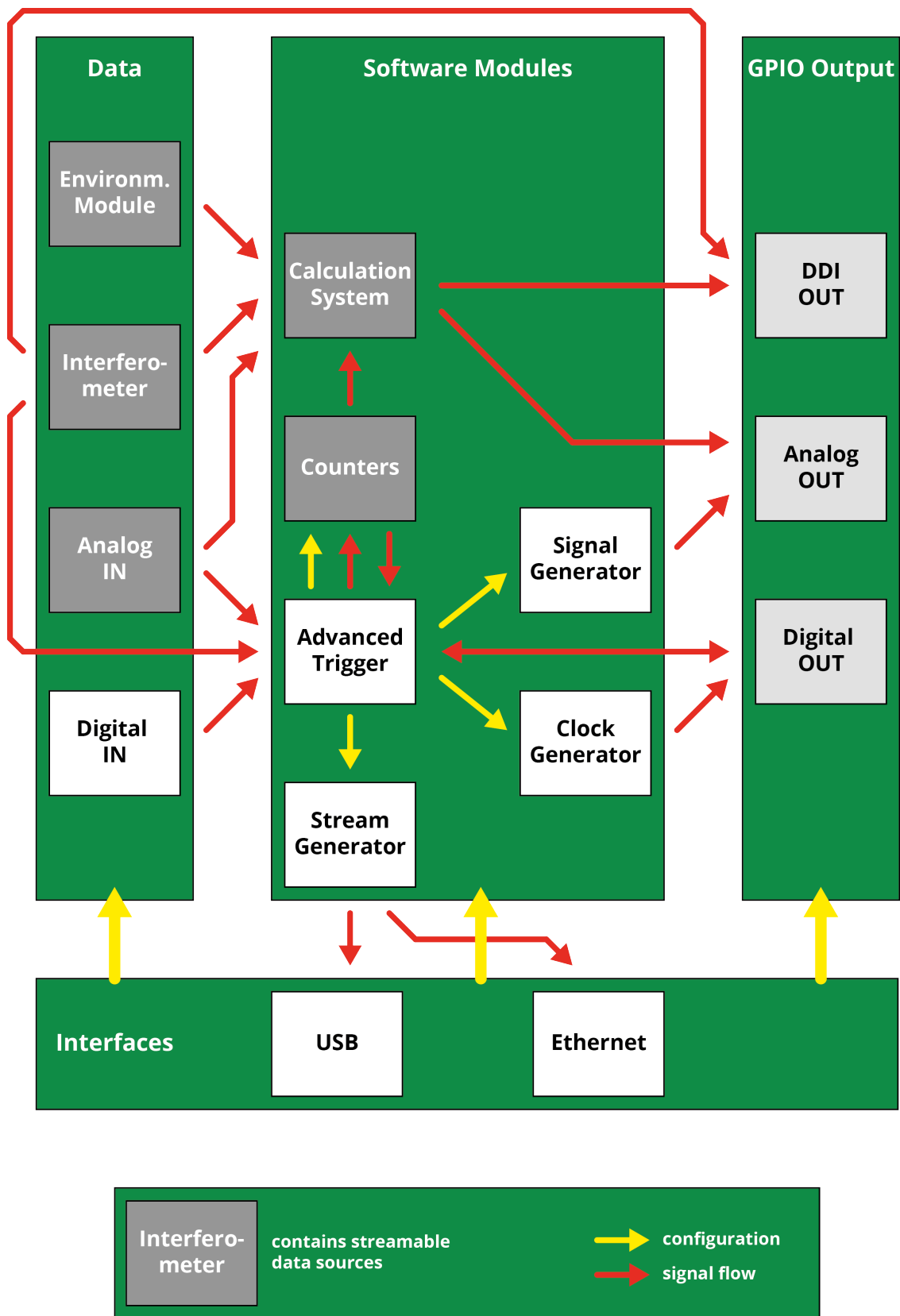
Figure 4.1: Overview of all **PICO**SCALE modules and their possible dependencies.

4.1.3 Digital and analog GPIO, AquadB

The general purpose input/output (GPIO) interface contains analog-to-digital (ADC) as well as digital-to-analog converters (DAC) to digitize external signals and output data, respectively. For example, it can output signals from the Clock Generator, Signal Generator, Calculation System and the Advanced Trigger module. On the other hand, external signals can be interfaced with the **PICO**SCALE. Thus, the GPIO interface allows to synchronize external devices with the **PICO**SCALE and vice versa.

In combination with the Signal Generator module or Stream Generator module, function generator and oscilloscope functionality can be realized. Please refer to section 7.4.1 for details.

4.1.4 Clock Generator

The Clock Generator module can provide up to two clocks with user defined frequency and phase. Both clocks can be synchronized. Each clock generator may run in a direct mode or it may be started and stopped by user defined trigger events. Each clock can be used in the GPIO interface for both digital and analog processing. A detailed description of the Clock Generator module can be found in section 7.5.1.

4.1.5 Signal Generator

In the Signal Generator module pre-defined shapes (sine, square, sawtooth) with user defined amplitude, offset, phase and frequency can be configured that may then be used within the GPIO interface. Furthermore, custom signal shapes can be uploaded to the module. A detailed description of the Signal Generator module can be found in section 7.5.2.

4.1.6 Calculation System

The Calculation System allows real-time processing of position data, GPIO data or environmental data, for example. In total, three calculation systems can be configured and their output can either be streamed or used in the GPIO interface. A detailed description can be found in section 7.5.3.

4.1.7 Counters

The Counter module allows to count either internal clocks (e.g., to use them as a timer) or trigger events. This can be done either directly, or the counter can be started and stopped by triggers. In total, two counters can be configured that may either be displayed in the Stream Monitor or they may be used as source for trigger events. A detailed description of the counters is given in section 7.5.4.

4.1.8 Environmental Module

The Environmental Module is an accessory that records temperature, humidity and the pressure of the surrounding of the **PICO**SCALE. These data influence the refractive index of the air. By tracking the environmental data the position data calculated by the **PICO**SCALE can be corrected for the respective fluctuations.

4.2 Data sources

Data sources are the basic data elements that provide data of any digital form over time. Position of the target mirror, environmental temperature or GPIO data are data sources, for example. Data sources that are related to each other are bundled into a channel.

The values of data sources may be retrieved from the device by streaming or polling them to the user PC. The user may select a sub set of all available data sources and let the device stream the values of these data sources over a period of time. An overview of all available data sources is given in table 4.1.

Table 4.1: Overview of all streamable data sources. The data sources that are provided by the modules are bundled into channel 1.

Channel 1	Channel 2	Channel 3
Position	Position	Position
Velocity	Velocity	Velocity
Acceleration	Acceleration	Acceleration
S(ω) raw	S(ω) raw	S(ω) raw
S(2ω) raw	S(2ω) raw	S(2ω) raw
S(ω)	S(ω)	S(ω)
S(2ω)	S(2ω)	S(2ω)
Counter 1&2		
Env. module temperature		
Env. module humidity		
Env. module pressure		
GPIO ADC 1-3		
Calculation System 1-3		

4.3 Signal flow

The **PICO**SCALE signals can be divided into three categories: optical signals, analog electrical signals and digital signals. The basic and simplified signal flow is shown in figure 4.2.
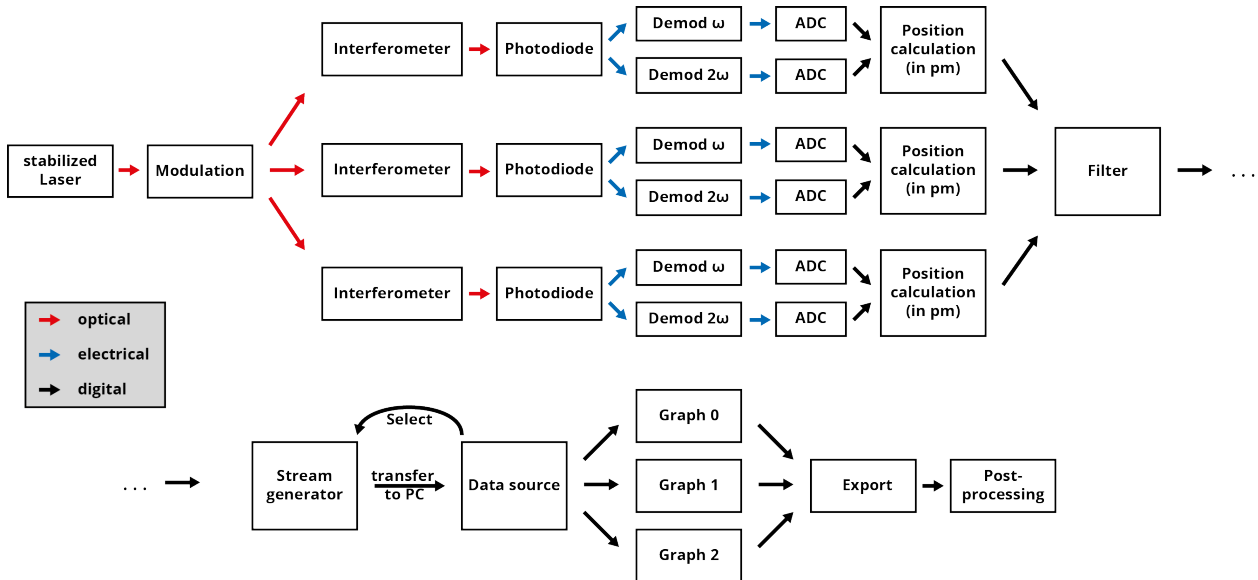

Figure 4.2: Signal flow in the **PICO**SCALE.

At the beginning, an optical signal (light) is generated by a wavelength stabilized DFB laser diode. The infra-red light is phase modulated with a frequency of $\omega = 30$ MHz and sent to the three sensor heads. The interferometric signals generated in the sensor heads are detected by photo detectors and converted into electronic signals.

The individual photo-electric signals are demodulated by both the modulation frequency and its second harmonic (60 MHz). The resulting demodulation signals are digitized by analog-to-digital converters (ADCs).

The digital signals are used to perform the position calculation. After appropriate filtering, the data stream is configured and the data are transferred to the user PC. You can select the desired data sources and display them in graphs. Finally, the data can be exported to csv-files to be available for data post-processing.

> **NOTICE**
>
> The position values, generated in the FPGA, have a resolution of 1 pm. Thus, all internal modules, especially the Advanced Trigger System and the Calculation System, process integer numbers with the unit picometer.

4.4 Adjustment auto function

In the **PICO**SCALE auto functions are complex configuration processes that, once triggered, automatically perform a sequence of internal routines to optimize the system performance. The adjustment auto function performs certain procedures to achieve high accuracy of position data and must be run once before measurement. It has three states:

- Disabled
  By default the auto function is disabled.

- Manual Adjustment
  In this state you have to adjust the targets that reflect the laser back into the sensor head in order to get the highest possible signal quality. Once satisfied, the user must start the automatic adjustment routine to complete the adjustment.

- Automatic Adjustment
  In this state the device performs internal signal optimization routines to improve the accuracy of the position data. After this procedure, the activated channels will generate valid position data and you can start measuring.

4.5 Events

In some situations events might occur that require further attention or reactions by the user. To avoid that the status of the device has to be permanently checked, the **PICO**SCALE offers a notification system that you may configure to your needs. By default, the most important alerts are enabled.

For example, a *beam interrupt* event is produced if the probe beam is disturbed such that the signal quality has fallen below a certain level. If at some point the signal quality is sufficiently high again, a *beam restored* event is sent. This information is important as you have to check if the position data are still valid. Within the *Advanced Trigger* module, this event can be used as trigger source which can be forwarded to a GPIO pin, for example. This way, you may react to unforeseen incidents in the experimental setup and stop moving parts, for example.

4.6 System filters

Most **PICO**SCALE data sources are subject to low pass filtering before they are provided to other internal modules. Compared to depricated **PICO**SCALE firmware versions[1], this has the advantage that the following modules can operate with filtered data:

- **Calculation System.** Data are filtered before they can be processed in the module

- **Advanced Trigger.** Triggers can be set up to react on filtered data

- **Digital Differential Interface.** Filtered data can be output via the AquadB or SD protocol

---

[1]In previous firmwares – older than 1.4.3 – the filters were implemented in the stream generator module. Therefore, only data that were actually streamed via USB or Ethernet were subject to low pass filtering. If data sources were used within the Calculation System, Trigger System etc or output via AquadB interface, the data were suffering increased noise.

> **NOTICE**
> When the data are streamed via USB or Ethernet, filter rate and frame rate have to be matched. This is important as an inappropriate sample rate may lead to oversampling or aliasing. In the **PICO**SCALE GUI, potential aliasing is indicated by a small warning sign and the frame rate can easily be adapted to the filter.

> **NOTICE**
> When SmarAct's motion controller MCS2 is connected, the filter rate is fixed to 39.06 kHz to match the MCS2's sample rate and thus to avoid aliasing.

4.7 Streaming aggregation

When data sources are streamed to the **PICO**SCALE via USB or Ethernet, the **PICO**SCALE usually bundles a certain amount of data before it sends them. This so-called aggregation decreases the communication overhead significantly. If data are streamed with a specific frame rate, the **PICO**-SCALE automatically uses a convenient aggregation size. This aggregation size is roughly set to provide about 20 data packages per second. The protocol works most efficient if the aggregation size is a power of 2, i.e.

$$\text{Aggregation} = 2^n, \quad n \in \mathbb{N}$$

However, if an external clock is used as frame rate, the **PICO**SCALE cannot know the precise frame rate and thus also an aggregation size cannot be estimated. The user has to set the desired aggregation manually. In the following table please find an overview on the frame rates and respective aggregation size the **PICO**SCALE uses for direct streaming (i.e., an internal clock is used as frame rate), which may serve as and rule-of-thumb to set the aggregation.

4.8 Network discovery protocol

The **PICO**SCALE network discovery protocol enables to list all available **PICO**SCALEs in your local network. Within the **PICO**SCALE GUI you may then easily select the appropriate device without typing in the IP address after every startup of the **PICO**SCALE or restart of the GUI. See chapter 7 for usage of the protocol with the GUI.

Table 4.2: **PICO**SCALE frame rates and corresponding aggregation sizes.

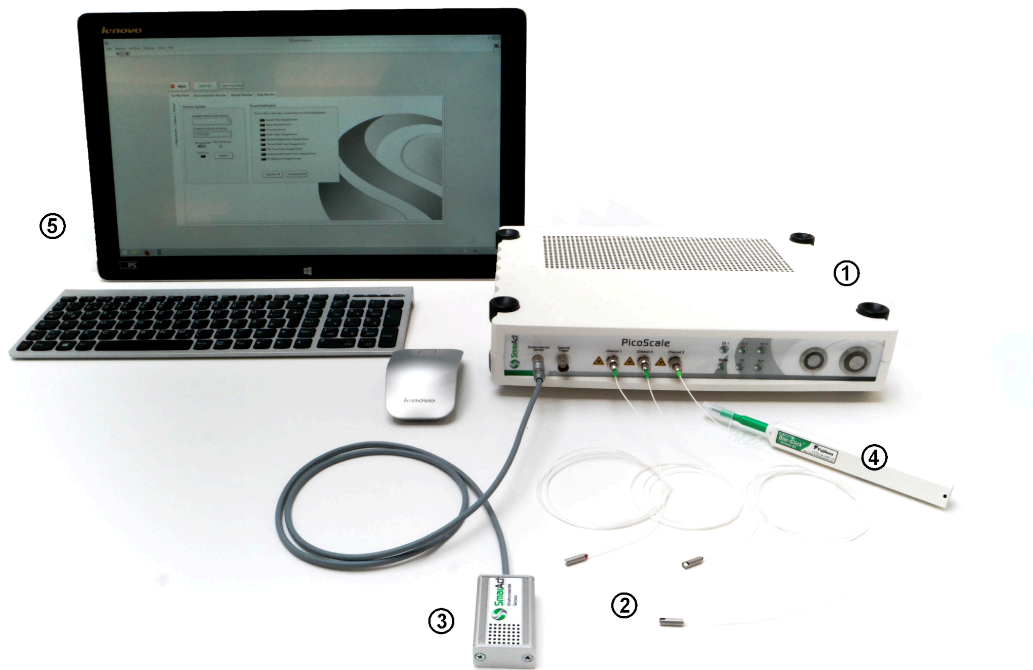| Frame rate	Aggregation
10 / 5 / 2.5 / 1.25 MHz	1024
625 / 312.5 / 156.25 / 78.13 / 39.06 kHz	1024
19.53 kHz	512
9.77 kHz	256
4.88 kHz	128
2.44 kHz	64
1.22 kHz	32
610 Hz	16
305 Hz	8
152 Hz	4
76 Hz	2
38 / 19 / 9 / 4 / 2 / 1 Hz	1

5 *PICOSCALE HARDWARE*

Figure 5.1: Basic accessory, consisting of (1) **PICO**SCALE Controller, (2) sensor heads, (3) Environmental Module, (4) One-Click cleaner and (5) User PC.

This chapter provides an introduction to the **PICO**SCALE Hardware. The basic accessories are shown in figure 5.1. The main component is the **PICO**SCALE Controller. It is available as a table-top version (1) and a 19" rack version. Up to three measurement heads (2) and an environmental module (3) can be connected to the controller. Typically each **PICO**SCALE system is shipped with some additional accessory (4) like a One-Click cleaner pen, head adapters, mirror mounts, etc. Finally, a PC (5) is required. It is not part of the **PICO**SCALE system and must be provided by the user.

5.1 **PICO**SCALE **controller**

The **PICO**SCALE Controller contains the laser source, various optics and detection electronics. It furthermore holds the position calculation unit, which is a hybrid system with a high performance FPGA and an embedded PC. This combination guarantees maximum flexibility and highest performance.
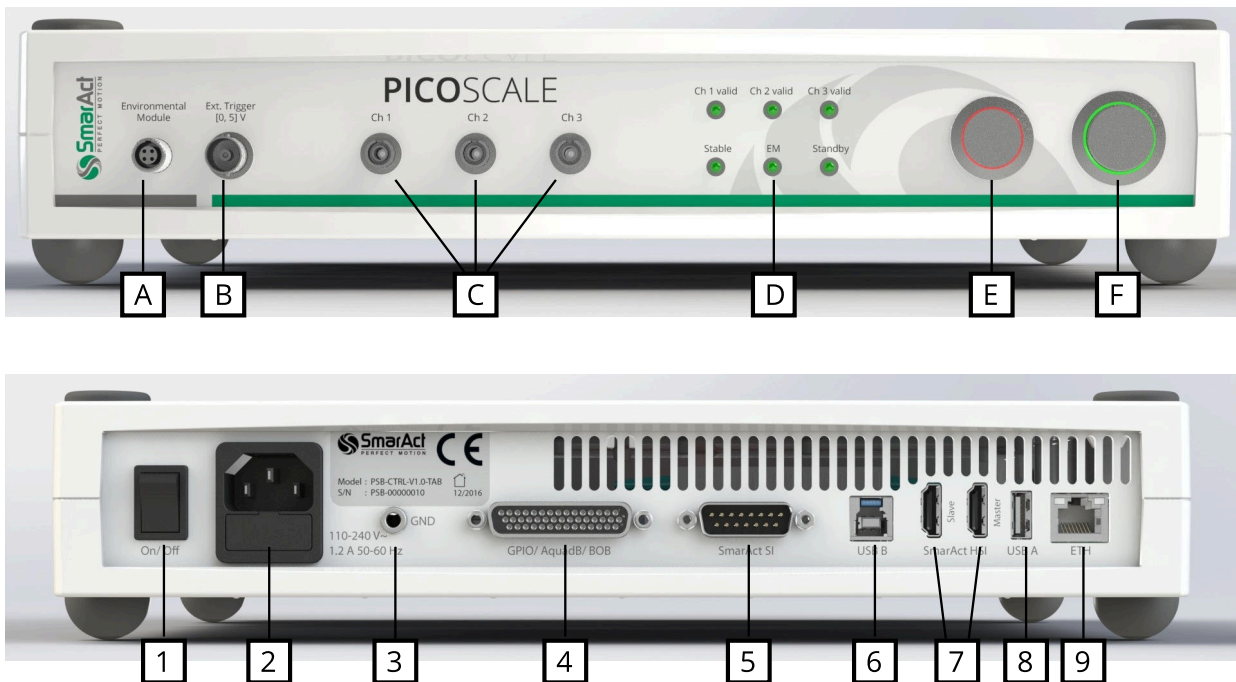
Figure 5.2: (top) Front side of the **PICO**SCALE Controller with different connectors for the (A) environmental module, (B) external trigger connector, (C) sensor heads, (D) status LEDs, (E) pilot laser and (F) power button. (bottom) Back side of the **PICO**SCALE Controller with the (1) main power switch, (2) power connector (fuse included), (3) ground connector, (4) GPIO and AquadB connector, (5) SmarAct sensor interface, (6) USB slave interface, (7) SmarAct high-speed sensor interface, (8) USB master interfaces and (9) Ethernet connector.

Figure 5.2 shows the front and back side of the **PICO**SCALE Controller. The front side exhibits inputs for the environmental module (A), external trigger signals (B) and up to three measurement heads (C). The environmental sensor is connected to the **PICO**SCALE simply by plugging the module connector into the connector at the **PICO**SCALE housing. Red marks on the connector and socket indicate the correct orientation.

The external trigger input is a BNC connector with an input range of [0,5] V. Internally, this trigger input has a pull-up resistor (10 kΩ). Thus, the external trigger is always logically high when nothing is connected to the input.

The optical inputs/outputs for up to three measurement heads are FC/APC connectors. It is important, that only FC/APC connectors are used. Since these connectors have an 8°-angled end face, the orientation is crucial. Thus, the male connectors have keys, while the receptacles have corresponding slots. It is mandatory to clean both, male and female connectors, with an appropriate fiber cleaner (see chapter 6.3 for further information).

The status LED panel (D) offers a convenient overview of the system state. At the top, three LEDs indicate the *channel valid* status. A channel becomes valid after the **PICO**SCALE sensor head adjustment and the corresponding automated optimization routines have been successful. At the bottom, the first LED indicates if the system is stable, which means that the wavelength of the laser is actively stabilized. The **PICO**SCALE is ready for a measurement, if the desired channels are valid and the system is stable. The next LED marks, if an active connection to an environmental

module is established. The last LED indicates if the device is in standby mode. On the right hand side of the front panel there is the pilot laser button (E) and the power button (F). Once the system has fully booted, pressing the pilot laser button activates the red adjustment lasers of all three channels. Active pilot lasers are indicated by the red LEDs integrated into the button. The power button turns the system on (if it is in standby mode) or off. The two front panel buttons are also used to update the controller firmware, see chapter 6.6.1.

On the left side of the back panel there is the main power switch (1). When the main power is turned on, the device is in standby mode and can be started with the power button at the front panel. Next to the main power switch, there is the power connector (2) with integrated fuse. The allowed input voltage range is [90,246] V_{AC} with a maximum current of 0.5 A_{RMS} and an AC frequency between [47,63] Hz. The power input is protected with a 2.5 A slow blow fuse. For very sensitive measurement setups, the **PICO**SCALE offers a PE socket (3) to reference connected devices to the same ground potential. The GPIO and the AquadB interface (4) are available via a D-Sub 44HD connector. For convenient access to all GPIOs and the DDI interface, a Breakout-Box (BOB) is available as accessory for the **PICO**SCALE Controller, which is connected via the 44 pin connector. The **PICO**SCALE offers two bidirectional, high-level interfaces, USB and Ethernet. For USB connection, the user PC is connected to the USB slave interface (6), for Ethernet correspondingly to the Ethernet jack (8). Additionally, two integrated USB master interfaces are connected to the embedded PC. Via these interfaces a software update can be installed, for example.

Besides the main, high-level interfaces, the **PICO**SCALE offers two low-level interfaces. The SmarAct SI (5) and SmarAct HSI (7) allow direct access of other SmarAct products to the **PICO**SCALE data sources.

5.2 Interfaces

To work with the **PICO**SCALE Controller the system has to be connected to a PC. Therefore, a USB 2.0 slave and a GBit Ethernet interface can be used. Both interfaces can be used at the same time so that up to two users can connect to the system via Ethernet and USB. This allows that data can be read out from several terminals at the same time. However, to prevent unintentional reconfiguration, only one user has full access and the ability to configure the system.

The **PICO**SCALE offers a multitude of analog as well as digital interfaces to input or extract data to and from the device, respectively. This guarantees a seamless integration in laboratory setups with great flexibility that goes far beyond interferometric position measurements.

5.2.1 Environmental Module interface

The Environmental Module is connected to the **PICO**SCALE Controller with a four wire interface. The communication to the **PICO**SCALE Controller is realized by a UART protocol, and the power supply of the Environmental Module is also provided by this interface.

5.2.2 Optical outputs

> **CAUTION**
> **Laser outputs.** The **PICO**SCALE Controller contains an infrared diode laser with an output of less than 0.2 mW at 1520 nm - 1580 nm and a red diode laser with an output power of less than 0.6 mW at 650 nm. Do not stare into the beam and ensure the laser light is always appropriately guided.

The **PICO**SCALE Controller has three optical outputs at the front panel of the chassis. Directly after start up, the infrared measurement laser is enabled. This laser source has an output power of maximum 0.2 mW per channel at a wavelength of 1520 nm - 1580 nm.

To improve the adjustment of the interferometer heads the **PICO**SCALE Controller provides the possibility to switch on a red pilot laser with the pilot laser button on the front panel. The pilot laser has a output power of max. 0.6 mW per channel at a wavelength of 650 nm. It has no influence on the measurement of the **PICO**SCALE Controller.

5.2.3 Power connection

Connect the **PICO**SCALE Controller only with the provided IEC power cord and properly established protective earth. After connecting the power cord use the main power switch to set the system into standby mode. Finally press the power button on the front panel to start the system.

Change the main fuse

The **PICO**SCALE Controller is protected with a 2.5 A glass tube fuse with a slow blow timing behaviour. To prevent permanent damage or fire, the fuse must only be replaced with an equivalent fuse if required (e.g. ESKA No. 522.500). The dimension of the glass tube is 20 x 5 mm.

> **WARNING**
> To prevent electrical shock, remove the power cord from the **PICO**SCALE Controller before replacing the fuse.

To change the fuse, remove the power cord and open the fuse holder (see figure 5.2). There are slots for two fuses. The first slot contains the active fuse, in the second slot a fuse for replacement is included. Remove the damaged fuse and replace it with a slow blow 2.5 A glass tube fuse with the dimension of 20 x 5 mm.

5.2.4 USB slave interface

The USB slave interface is one of the main bidirectional communication interfaces of the **PICO**-SCALE Controller. It provides a USB 2.0 high speed connection with data-rates of up to 480 Mbits/s.

5.2.5 Ethernet interface

The Ethernet interface is the second main bidirectional communication interface of the **PICO**-SCALE Controller. The interface is configured via the embedded PC and is able to provide GBit Ethernet. To use the full performance of the **PICO**SCALE Controller, a GBit Ethernet connection is required.

5.2.6 USB master interface

The USB master interface is connected to the embedded PC. Via this interface software updates can be installed, for example (see chapter 6.6.1 for more information).

5.2.7 SmarAct Sensor Interface (SI)

> **NOTICE**
> The SmarAct sensor interface is sensitive to electrostatic discharge. Please use wrist straps when using this interface.

The SmarAct SI interfaces the **PICO**SCALE Controller with other SmarAct products, e.g. the Modular Control System 2 (MCS2). In this configuration the **PICO**SCALE Controller may act as sensor module for the motion system.

5.2.8 SmarAct High Speed Sensor Interface (HSI)

The SmarAct HSI is an optional interface to connect other SmarAct systems with the **PICO**SCALE Controller. This interface has the advantage that data can be transceived with data-rates up to 6.5 Gbit /s. This allows to perform very fast data processing with high resolution.

5.2.9 GPIO and Digital Differential Interface

The D-Sub 44HD connector provides several interfaces including analog and digital GPIOs as well as Digital Differential Interfaces (DDI) for all three channels. Each DDI channel can either act as an AquadB or a serial interface. These additional interfaces make the **PICO**SCALE Controller a very versatile laboratory measurement instrument as it provides the functionality of signal generators, trigger systems, signal trackers and position measuring sensor in one device. This integration

in one device also has the advantage that different data sources are synchronized and can be handled with a single tool.

For easy access to the signals we recommend to use the **PICO**SCALE Breakout-Box which is described in chapter 5.3. It includes additional buffering of analog and digital IOs and splits the D-Sub 44HD connector to BNC connectors. However, for direct access via the D-Sub 44HD connector, please contact SmarAct for information on the pin assignments.

5.3 Breakout-Box

Figure 5.3: Breakout-Box connectors overview.

The **PICO**SCALE Breakout-Box (BOB) provides simple and convenient access to the great variety of signals at the DSub 44HD connector. The chassis of the Breakout-Box is the same as the chassis of the **PICO**SCALE Controller and BOB can be stacked on top of a **PICO**SCALE Controller. Ventilation holes of the **PICO**SCALE Controller are passed on to the Breakout-Box, so that heated air can disappear freely. Do not cover the holes to prevent overheating of the **PICO**SCALE Controller!

The connectors on the top of the Breakout-Box are placed in three groups. AquadB outputs are placed on the left hand side, digital GPIOs can be found in the center and analog GPIO pins are on the right hand side (see figure 5.3). Analog and digital GPIOs can be connected via BNC connectors while the AquadB signals are mapped to DSub 15 connectors.

5.3.1 Differential Digital Interface DDI

The Differential Digital Interface (DDI) provides two differential digital signals, which can be used for different digital protocols, e.g. AquadB and Serial Data. With the Breakout-Box the signals are distributed to three DSub 15 connectors, one per channel. The pin assignment is shown in figure 5.4 and specified in table 5.1.
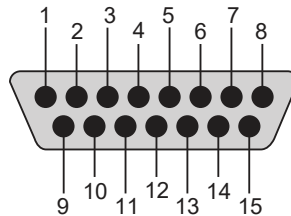

Figure 5.4: Pin assignment of the DSub 15 connector.

Table 5.1 – Pin assignment of DSub 15 AquadB connectors

Signal	Direction	AquadB	serial data
1	Out	A positive	CLOCK positive
2	Out	B positive	DATA positive
3 - 7	-	not connected	-
8	-	System Ground	System Ground
9	Out	A negative	CLOCK negative
10	Out	B negative	DATA negative
11 - 15	-	not connected	-
Shielding	-	System Ground	System Ground

The output levels of the specific DDI pins are illustrated in figure 5.5. Main performance parameters are listed in 5.2.
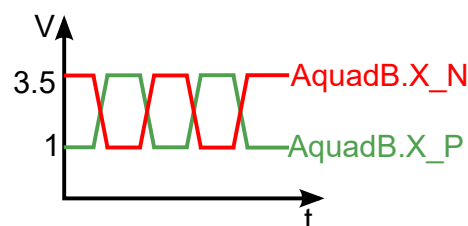

Figure 5.5: Output level of the specific pins of the AquadB connector, where the *X* is to be replaced by the individual channel number and quadrature (A or B). The indices *P* and *N* denote the positive and negative part of a differential AquadB pair.

Table 5.2: Main performance data DDI

Parameter	Typical Value	Unit	Comment
$V_{O_{Diff}}$	0 - 5	V	Differential output voltage
$V_{IH_{Diff}}$	0.2	V	Differential high-level input voltage
$V_{IL_{Diff}}$	-0.2	V	Differential low-level input voltage
f_{max}	5	MHz	Max. frequency per differential pair

BOB AquadB

Industry standard AquadB receivers are often able to receive differential quadrature signals as provided by the **PICO**SCALE Controller. In figure 5.6 the AquadB signals are shown schematically. With the signals A and B four states can be encoded, each state indicates a position increment. So the maximal increment frequency is 4 times the maximum differential pair frequency, in this case 20 MHz.
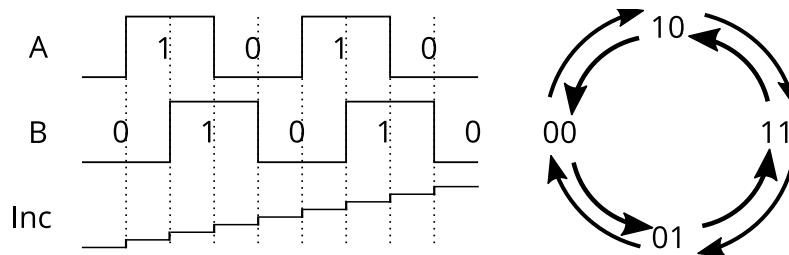

Figure 5.6: Scheme of the differential A and B signal and the according position increment of the Quadrature interface.

The direction of the position change is given by the order of the cases.
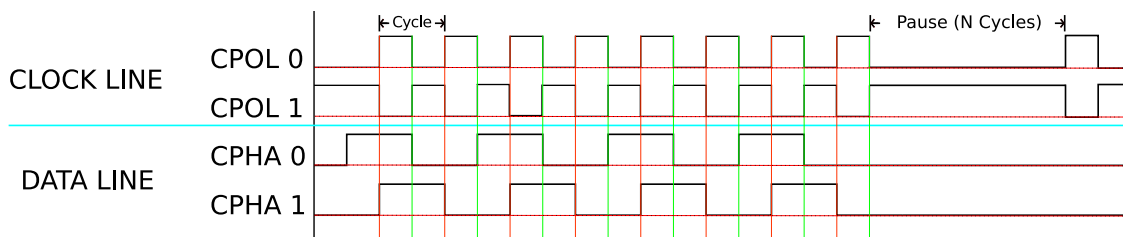
BOB Serial Data

Figure 5.7: Clock and data cyles on the serial interface. The CLOCK LINE can either have a negative zero level or a positive zero level. The DATA LINE can either be written with rising or the falling edge of the clock.

Each of the three DSub 15 connectors can be configured to act as a serial data output. In figure 5.7 the options are illustrated. The upper part of the figure shows the options of the clock line and

the lower part shows the options of the data line.

- (CPOL 0): The CLOCK LINE has a negative zero level .
- (CPOL 1): The CLOCK LINE has a positive zero level.
- (CPHA 0): The DATA LINE is written with the beginning of each clock cycle.
- (CPHA 1): The DATA LINE is written at the center of each clock cycle.

Furthermore, you can choose the data idle polarity.

5.3.2 BOB digital GPIOs

The digital GPIOs are buffered on the Breakout-Box. The signals labelled with Digital1 - Digital4 have a 5 V high level, while the Digital5-Digital9 signals have a 3.3 V high level. All digital GPIOs are matched with a 50 Ω serial resistor. The direction of the buffers is automatically set with the direction of the digital GPIOs within the **PICO**SCALE Controller. Main performance parameters are listed in table 5.3 (for the Digital 1-4 signals) and table 5.4 (for the Digital 5-9 signals).

Table 5.3: Main performance data BOB Digital 1-4 GPIO Buffer

Parameter	Typical Value	Unit	Comment
V_O	0 - 5	V	Digital 1-4 output voltage
V_{IH}	3.5	V	High-level input voltage
V_{IL}	1.5	V	Low-level input voltage
rising/falling edge	$\leqq 50$	ns	

Table 5.4: Main performance data BOB Digital 5-9 GPIO Buffer

Parameter	Typical Value	Unit	Comment
V_O	0 - 3.3	V	Digital 5-9 output voltage
V_{IH}	2	V	High-level input voltage
V_{IL}	0.8	V	Low-level input voltage
rising/falling edge	$\leqq 50$	ns	

Due to the limited bandwidth it is recommended to use the digital GPIOs with a maximum frequency of 1 MHz. Using higher frequencies may cause asymmetries in the duty cycle of the signal. Depending on the cable connected to the BNC connector the digital GPIOs can over-/undershoot with up to 1 V. The best signal form can be achieved in a 50 Ω environment and with short connections.

5.3.3 BOB analog GPIOs

The Breakout-Box buffers and normalizes the analog GPIOs to single ended signals with an amplitude of ±10 V.

At the input ADC1 the single ended ±10 V signal is converted to a differential signal with an amplitude equivalent to a full scale modulation of the ADC. Due to component tolerances, offsets and gains can vary slightly so that ±10 V is not exactly equivalent to the ADC's resolution. For an exact mapping of voltage to ADC resolution it is recommended to do a calibration of the ADC input. The input impedance of the ADC1 input is approx. 2.4 kΩ. The inputs ADC2 and ADC3 input are converted a differential signal. Again, it is recommended to do a calibration to get an exact mapping from voltage to ADC resolution. The input impedance is approx. 34 kΩ. For a performance overview see table 5.5 and 5.6.

Table 5.5: Main performance data of ADC1

Parameter	Typical Value	Unit
Full-scale input voltage	±10	V
Sample-rate	10	MS /s
Resolution	16	Bit
Bandwidth f_{1dB}	2-2.5	MHz

Table 5.6: Main performance data of ADC2 and ADC3

Parameter	Typical Value	Unit
Full-scale input voltage	±10	V
Sample-rate	100	kS /s
Resolution	16	Bit
Bandwidth f_{1dB}	35-45	kHz

The Breakout-Box converts the differential DAC1 signal from the **PICO**SCALE Controller to a single ended ±10 V output signal. The output can drive currents up to 35 mA and a capacitive load up to 33 pF. DAC2-DAC5 are the **PICO**SCALE DAC signals normalized to ±10 V. If a single DAC channel is connected, it can drive currents up to ±30 mA and a capacitive load of up to 200 pF. With more channels connected, the maximum current reduces correspondingly. For a performance overview see table 5.7 and 5.8.

Table 5.7: Main performance data of DAC1

Parameter	Typical Value	Unit
Full-scale output voltage	±10	V
Sample-rate	10	MS /s
Resolution	12	Bit
Bandwidth f_{1dB}	2-2.5	MHz

Table 5.8: Main performance data of DAC2-5

Parameter	Typical Value	Unit
Full-scale output voltage	±10	V
Sample-rate	200	kS /s
Resolution	16	Bit
Bandwidth f_{1dB}	130-170	kHz

5.4 Sensor heads
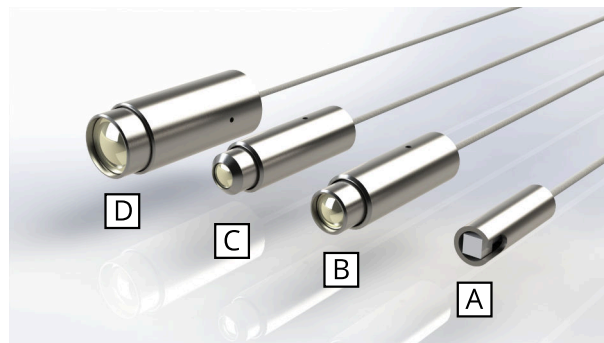
Figure 5.8: Selection of **PICO**SCALE sensor heads: (A) PS-SH-C01, (B) PS-SH-F01, (C) PS-SH-C03, (D) PS-SH-C02.

The **PICO**SCALE interferometer sensor heads are based on an optical fiber, a fiber ferrule, a collimator and a beam splitter cube. The optical fiber (single mode, minimum bending radius 10 mm) is terminated with a 8° ferrule. The angle is introduced to suppress parasitic interferences. A gradient index (GRIN) lens (also with 8° angle) is glued to the ferrule and used to collimate the laser beam. The key component is the beam splitter cube. The beam is split into two parts. One part is guided to the reference mirror that is coated to one of the surfaces of the cube. The other part is guided to the target. Given proper alignment, the probe beam interferes with the reference beam in the beam splitter cube. The interfering light is guided through the optical fiber back into the **PICO**SCALE Controller, where it is detected by a photo detector and the interference pattern is evaluated.
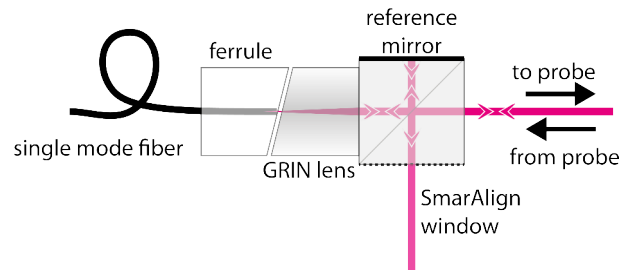
Figure 5.9: Setup of a **PICO**SCALE sensor head.

The open port of the beam splitter cube is the SmarAlign window. In specific sensor heads (for example sensor head type C01) it can be used as a monitor to superimpose the beams reflected from the reference and target mirror, respectively, using the visible pilot laser beam that is diffusely scattered at this surface. All standard components are mounted in a titanium sleeve.

5.5 Environmental Module

Figure 5.10: Environmental Module

To measure the environmental parameters (temperature, pressure, humidity), an environmental module can be connected to the **PICO**SCALE Controller. Since the measurement of the environmental conditions is most meaningful close to the sensor head, the environmental module has a small chassis to make it possible to place it in close vicinity of the heads. The environmental module is contained in an aluminum housing as small as 32x50x16 mm³. A microprocessor collects the data of the individual sensors and sends them to the FPGA for further processing. The measurement bandwidth is 1 Hz which is sufficient to detect variations in the environmental conditions. The accuracy of the environmental module is:

- temperature: ± 200 mK

- pressure: ± 2 mbar

- relative humidity: ± 2%

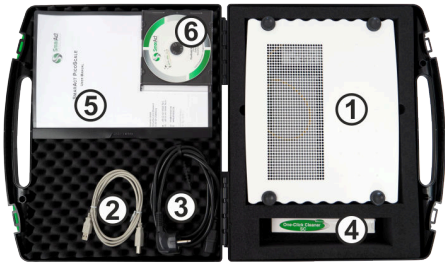These measurement uncertainties result in a position accuracy of typically <1 ppm.

6 *SETUP AND INSTALLATION*

The following chapter describes the installation of a **PICO**SCALE system. Since many of the **PICO**-SCALE components are fragile, please read and follow the information in this chapter carefully!

6.1 System checklist

If any cartons have been damaged, contact the shipper or SmarAct sales team at once. The shipping boxes for a standard **PICO**SCALE interferometer should contain the following equipment and documentation:

Table 6.1 – Components of a **PICO**SCALE System

Transport Case Image	Dimension and Weight	Content

	Height x Width x Depth:
	  15cm x 45cm x 40cm
	Weight:
	  5.94kg
		(1) **PICO**SCALE Controller
		(2) USB Cable
		(3) Power Cable
		(4) One-Click Cleaner Pen
		(5) User Manual
		(6) Software CD

	Height x Width x Depth:
	  4cm x 16cm x 15cm
	Weight:
	  0.20kg
		(7) Sensor Head
		(8) Data sheet

Table 6.1 – *Continued from previous page*

Transport Case Image	Dimension and Weight	Content
	Height x Width x Depth: 4cm x 16cm x 15cm **Weight:** 0.3kg	(9) Environmental Module (optional)
	Height x Width x Depth: 15cm x 45cm x 40cm **Weight:** 4.62kg	(10) Breakout-Box (optional) (11) BOB Cable (optional)

In case you have bought an in-vacuum system, there should be additional components like fiber feed-throughs and fiber patch cords. A complete list of all **PICO**SCALE components and accessory can be found on the SmarAct web page.

6.2 Unpack the system

1. Unpack the **PICO**SCALE system in an area that is clean and dry. Be very careful, especially with fragile optical and vacuum components.

2. Check each shipping container to be sure you have removed all transport cases and additional items. Do not discard the reusable shipping containers until it is certain that all items have been removed. It is recommended to keep the shipping containers in case you must return any equipment to SmarAct.

3. Open each transport case and unpack the system components.

4. You are now ready to set up the system in the desired location.

6.3 Cabling

For the first time installation, the **PICO**SCALE has to be connected via USB to the measurement PC. Note, that the PC is not part of the system and has to be supplied by the customer separately. Connect the included USB cable to the USB slave interface at the back side of the **PICO**SCALE Controller (figure 5.2, No. 6) and to the desired USB port at the user PC. After that, connect the power supply cable to the power connector at the back side of the controller (figure 5.2, No. 2).

Next, connect the measurement heads to the corresponding adapters at the front side of the **PICO**SCALE (figure 5.2, No. 4).

> ### NOTICE
> Glass fiber cables are very fragile and sensitive to bending. Please always respect a minimum bending radius of 30 mm, unless otherwise specified.

> ### NOTICE
> Please note, that dirt attached to the fiber end-face can significantly lower the system's performance or even destroy the fiber connector. In this case, the **PICO**SCALE and/or the corresponding sensor head has to be sent back to Smar-Act to get repaired.

To ensure optimal signal quality and also to prevent damage of the fiber surfaces, it is very important to clean all connectors first. This can be done using the One-Click cleaner pen which is part of our shipment, cf. figure 6.1. Open the plastic cap and push the plastic tube onto the glass fiber end piece until you hear a click. To clean the connectors on the **PICO**SCALE Controller or vacuum feedthroughs, remove the plastic tube on top of the fiber optic cleaner and then repeat the same process.
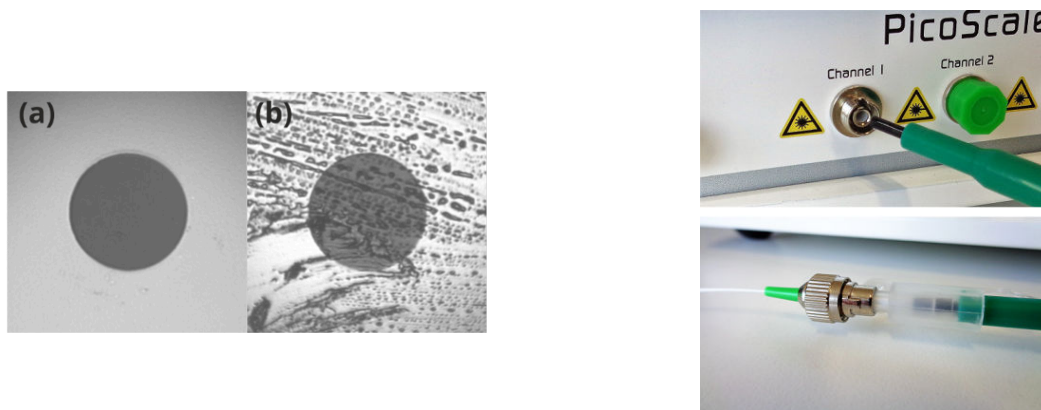

Figure 6.1: (left) Closeups of a clean (a) and dirty (b) fiber endface. Cleaning of the connectors and sockets using the One-Click pen is illustrated on the right hand side.

Figure 6.1 (a) shows a close-up of a clean end-face, while image (b) shows dirt accumulated on the end-face. On the right hand side cleaning of the fiber using the One-Click pen is illustrated. For a detailed description of the One-Click pen please refer to the brief application note delivered together with the tool.

When the fiber surfaces have been cleaned, gently plug the fiber connectors into the corresponding sockets. The key of the connectors must slide into the matching slot in the socket (fig. 6.2). Then fasten the connectors by turning the coupling ring.
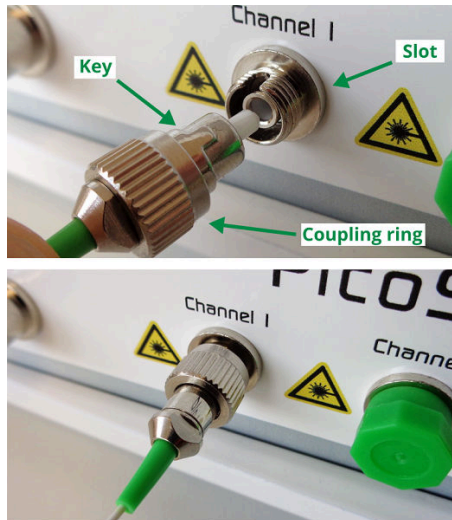
Figure 6.2: Connection of sensor head.

> ## NOTICE
> The **PICO**SCALE fiber network consists of FC/APC connectors. Do not plug any other optical connector types to the system or its subcomponents. This may cause significant damage to the optical system and dramatically drops the system performance.

If purchased, connect the environmental module to the system front panel (figure 5.2, No. 1). A red line and dot printed to the plug and connector mark the correct orientation. Place the sensor as close as possible to the measurement head(s), to ensure that the sensor measures the local environmental parameters, thus, reducing compensation errors.

The Breakout-Box (BOB) is connected using the included cable to the back panel of the **PICO**SCALE housing. Although the Breakout-Box is hot pluggable, it is recommended to connect BOB before the system is switched on.

> ## NOTICE
> The included BOB cable is quite sensitive to bending, thus respect a minimum bending radius of 50 mm. Please handle the large cable connectors with care and ensure that no pins are bent prior plugging.

6.4 System power up

Connect the power cable and press the main power switch on the back side (figure 5.2, No. 1). Now the standby LED at the front panel should be on, indicating an active power connection (figure 5.2,

No. 4). Press the power button at the right-hand-side of the front panel to power up the system (figure 5.2, No. 6). A green LED ring should now illuminate the power button. The status LEDs start blinking, indicating the boot sequence of the embedded controllers. After a few seconds, the LED blinking stops and the system is ready to use.

With the Pilot Laser button (figure 5.2, No. 5) at the front panel, an additional red laser can be activated, which is very helpful during the alignment of the sensor heads.

6.5 PICOSCALE software and API installation

The **PICO**SCALE Software provides you with a graphical user interface (GUI) as well as an application programming interface (API). For proper operation of the software Windows 7 or later should be used.

The minimum requirement regarding the cpu is an Intel Core-i5 processor of the fourth generation or similiar and 4 GB of RAM. Recommended is an Intel Core-i7 processor of the fourth generation or similiar with at least 3GHz and 8 GB of RAM.

To install the **PICO**SCALE software and API, open the included software CD and start the installer program `PicoScale_Installer_<version>.exe`. At first, the installer dialogue presents some important information about software and API changes. After confirming these information, you can select a destination folder (default: `C:\SmarAct\`). Lastly, you can select which components should be installed. After the installer is finished the **PICO**SCALE software and documentation can be found in the **PICO**SCALE folder in the destination path.

To uninstall the **PICO**SCALE software navigate to the Uninstall folder in the **PICO**SCALE main folder. Execute the program `unins000.exe`. After the program is finished, the complete **PICO**-SCALE software is removed from the system.

6.6 Firmware updates

SmarAct will release firmware updates for the **PICO**SCALE from time to time. Firmware updates usually contain updated software that fixes bugs, improves the system performance or adds new features. Some firmware updates can be skipped, because later updates contain all the content of earlier updates. However, some firmware version updates are required before later versions can be installed. This holds for relatively old firmware versions. For example, if your **PICO**SCALE has firmware version 1.0.5 installed, and you want to install version 1.1.7, you must first update to version 1.1.0 and then to 1.1.7. The following firmware versions have to be installed before updates to more recent versions are possible:

- `picoscale-1.1.0_2015-12-18_160315.fw` (contains **PICO**SCALE firmware version 1.1.0)

- `picoscale-2.0.0_2017-09-22_093253.fw` (contains **PICO**SCALE firmware version 2.0.0)

6.6.1 Performing a PICOSCALE firmware update

Firmware updates are files named like "`picoscale-1.0.1__2015-12-01_160436.fw`". The file must be copied to a USB memory stick, which has to be plugged into one of the **PICO**SCALE USB ports. For reducing problems, the stick should be empty (possibly freshly formatted) before copying the new firmware to it.

Before starting the update process, the **PICO**SCALE has to be switched off. Hold the pilot laser button and switch the device on, by pushing the power button. Do not release the pilot laser button until it starts blinking, which indicates that the device is in the update or reconfiguration mode.

> ### NOTICE
> It is important that the update process is NOT INTERRUPTED by switching off the power supply. Otherwise the device may become unresponsive and must be sent in for repair!

The update process may take a few minutes (5-15). When it has finished, the device will be in its normal operation mode and the pilot laser button should have stopped blinking.

> ### NOTICE
> In rare cases the update procedure does not finish after a few minutes. This problem may occur when updating **PICO**SCALE Controllers with an installed firmware version older than v1.1. If the pilot laser button does still blink after 30 minutes, please switch the device off and on. The device will continue its firmware update. During this phase, as described above, it must not be switched off. Now, the update should finish after a few minutes.

Some firmware updates may also require an update of the programming interface libraries (SDK) and the software tools for the **PICO**SCALE.

6.6.2 System diagnostics data

The **PICO**SCALE interferometer allows saving system diagnostics data (to a USB stick) for analysis of problems. To save diagnostics data, start the device and plug in a USB memory stick. Wait until it has booted and entered the normal operation mode. Hold the pilot laser button until it starts blinking (this should happen after at most 10 to 15 seconds).

> ### NOTICE
> It is important, that the device is in normal operation mode, **before** the pilot laser button is pressed!

When the blinking has stopped, you may unplug the memory stick. On the stick you will find two files: "`system.log`" and "`sysdiag_<uptime>_<bootcount>.dump`".

"`system.log`" is a text file that contains a list of important system activities, like successful or failed firmware updates. It may also include information about the reason why a system operation like a firmware installation has failed. The "`system.log`" can additionally be downloaded from the device using the **PICO**SCALE Control GUI, see chapter 7.

The "`sysdiag_<uptime>_<bootcount>.dump`" file contains status data in a binary format that can be sent to SmarAct for a detailed problem analysis.

7 PICOSCALE CONTROL GUI

The **PICO**SCALE can be controlled with the LabVIEW based graphical user interface (GUI). It contains all main functions to connect to a **PICO**SCALE system, to adjust it, read the device's status, configure all installed modules and, of course, read and process the data source values generated by the device.

In this chapter the GUI features are presented. First, it is shown how to connect to the device via different interfaces (USB and Ethernet) and read its status. Furthermore, the GUI exhibits an adjustment panel, which guarantees a quick and easy adjustment of the **PICO**SCALE system with user friendly auto-functions. Position data as well as other data sources can be displayed in the the Stream Monitor.
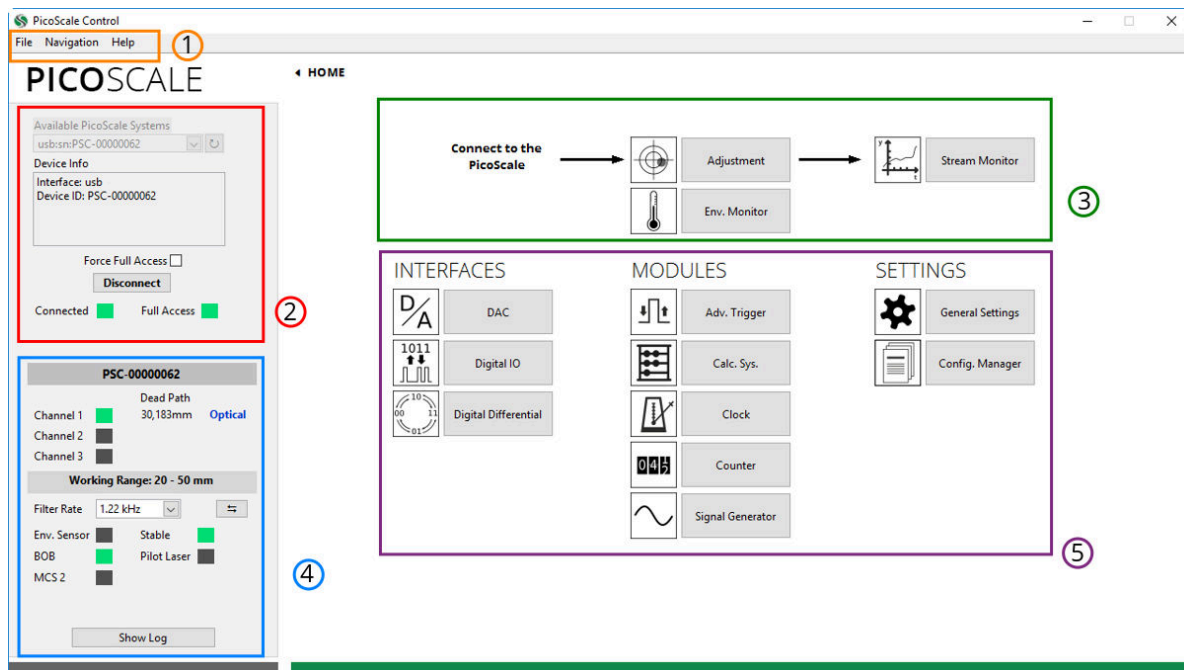

Figure 7.1: **PICO**SCALE GUI overview. (1) Menu (2) Connect to **PICO**SCALE (3) Adjustment, Environmental Monitor and Stream Monitor (4) **PICO**SCALE Status (5) Interfaces, Modules and Settings.

After the program is started you can see the HOME panel as shown in figure 7.1. All parts of the GUI can be reached from the HOME panel either by clicking on the corresponding buttons or with the menu (1). All available **PICO**SCALEs are listed in (2). After connecting to the system the adjustment and data streaming (3) as well as the **PICO**SCALE status (4) are available. All interfaces, modules and the general settings can be centrally reached (5).

7.1 Configuration of the PicoScale

When starting the GUI, the *HOME* panel seen in figure 7.1 is opened. All elements of the GUI can be reached from here.

7.1.1 Connecting to the controller

The **PICO**SCALE is a multi-user system and up to two users can be connected to the same instrument. Therefore, the device offers two interfaces, USB and Ethernet. When more than one user is connected to the instrument, the **PICO**SCALE requires one main user (full-access connection) who can control the system and change properties, for example. The other user can only extract data from the device.

You can connect to a **PICO**SCALE Controller in the *Connect System* menu, shown in figure 7.2. When the GUI is started, all **PICO**SCALE devices are listed with their ID-strings in the *Available PicoScale Systems* menu. You can refresh the list at any time with the *reload* button next to the drop-down menu. The *Device Info* shows additional information on the device like *Device ID*, *Info* about the system and *IP* address of an Ethernet interface. Below this field, you can check whether a full-access connection should be forced. If the *Force Full Access* check box is marked, all potentially existing full-access connections of other users are ignored and a full-access connection is established. When this box is unchecked, the GUI checks if a full-access connection is already set up. If not, it establishes a full-access connection, if yes, the **PICO**SCALE GUI connects with limited access. The *Full Access* LED indicates if a full-access connection is established.
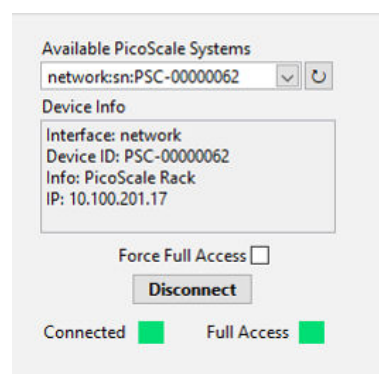

Figure 7.2: Connect System menu.

7.1.2 General settings

The basic setup of the system is located under *General Settings* in the *Home* panel. The **PICO**SCALE device generates user notifications, so-called *Events*. You can track these events to validate received data or check the experimental setup, for example. In the *Event Notification* menu you can subscribe or unsubscribe to events. It is located on the left side in figure 7.3. Especially if high streaming rates (close to 10 MHz) are used, it is recommended to unsubscribe from all unnecessary events in order to guarantee optimal performance of the **PICO**SCALE GUI. Subscribing or unsubscribing to a specific event can be done by clicking on the appropriate check box in the *Event Notification* menu. Furthermore, two buttons are available to subscribe or unsubscribe to all events. After connecting to a **PICO**SCALE Controller, the GUI subscribes to all events automatically. Note that higher level events, such as streaming events, cannot be unsubscribed. For detailed information on the event system, please refer to the **PICO**SCALE Programmer's Guide.

The *Network Configuration* menu at the center of figure 7.3 allows to define the Ethernet configuration used by the **PICO**SCALE system. If you use the Ethernet connection for the first time, we recommended to connect the **PICO**SCALE Controller via USB, set up the desired Ethernet configuration and reconnect to the **PICO**SCALE Controller via Ethernet.
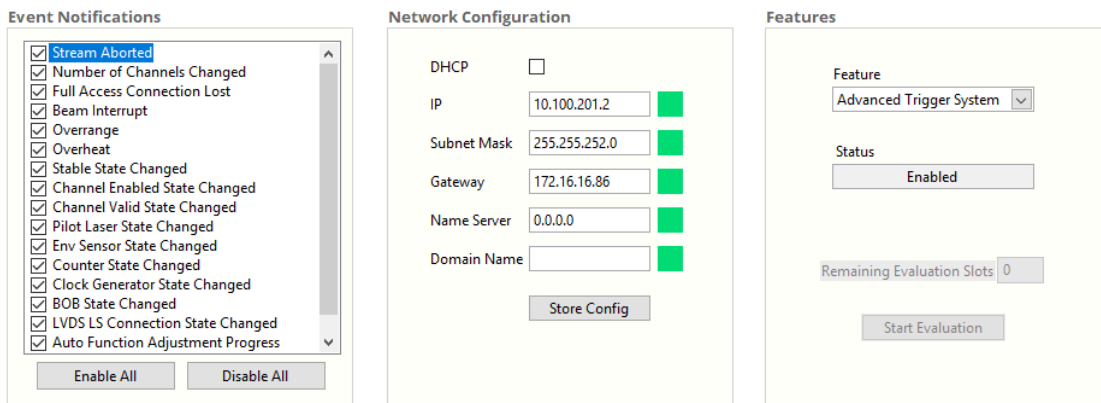
Figure 7.3: General Settings: (left) Configuration menu for *Event Notification*. (center) *Network Configuration*. (right) *Features* Configuration.

You may activate the Dynamic Host Configuration Protocol (DHCP) if your server supports automatic assignment of IP addresses. If activated, the other fields are deactivated and have no meaning. If DHCP is deactivated, a static *IP Address*, as well as other Ethernet properties like *Subnet Mask*, *Gateway*, *Name Server* and *Domain Name* can be configured in the appropriate panels. Once all properties are defined, the configuration can be transmitted to the system by clicking on the *Store Config* button. During transmission, the **PICO**SCALE checks the entered values, and if all values are valid (indicated by the green LEDs), the desired configuration is activated.

The **PICO**SCALE offers chargeable firmware upgrades, such as the *Advanced Trigger System*, the *Signal Generators* and the *Calculation System*. In the *Features* menu at the right hand side of figure 7.3, the available features are displayed in the *Feature* drop-down menu.

All chargeable features can be evaluated for a certain time. Generally, 10 time slots are available and can be activated individually. Each time slot allows to evaluate the selected feature for 8 hours. The remaining evaluation time slots are displayed in the *Remaining Evaluation Slots* fields. By clicking the *Start Evaluation* button, a new time slot is started.

If you decide to upgrade your system with the feature, please contact SmarAct. You will receive a firmware upgrade and the feature time is set to infinity automatically.

7.1.3 Status

The *PicoScale status* is located in the lower left part of the GUI and displays the current status of the system. The red box (4) in figure 7.1 illustrates the location. The active channels are marked with a green rectangle. The value *Dead Path* besides the active channels is calculated during the adjustment process and indicates the absolute distance between the measurement head and object mirror.

The working range of the system is displayed below the channel indicator. If the target leaves this range a new adjustment might be necessary. The *Filter Rate* describes a low pass filter that is applied to position and ADC data and can be adjusted with the drop-down list. It can be switched to the corresponding *Cut-off Frequency* using the button on the right side. The filter is implemented in the FPGA and determines the system bandwidth.

When the system recognizes optional components like the environment sensor, the Breakout-Box and the MCS2, the rectangle besides the components is green. With the button *Show Log* the log of the GUI can be displayed. It shows log entries in case of system start-ups and displays error codes. Each log entry is formatted with a date and time string and a clear text message. If the last log entry was a system error message the *Show Log* button has red borders. The *Clear* button deletes all log entries of the GUI.

All fields in the *PicoScale status* are updated automatically after connecting to a **PICO**SCALE system. The system information is important for all service requests.

The *System Log* of the **PICO**SCALE controller shown in figure 7.4 is located in the menu bar under *Help*. It contains a list of important system activities like the activation of optional software modules. It may also include information about the reason why a system operation like a firmware installation (cf. section 6.6.2) has failed. The information can be relevant for service requests and can easily be copied to the clipboard using the button *Copy to Clipboard*.
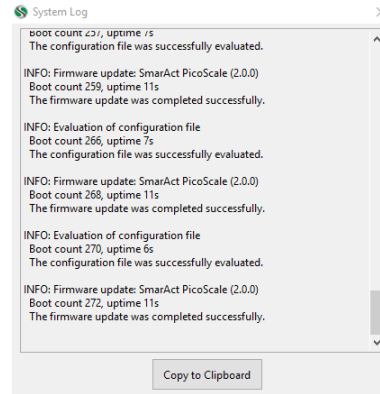

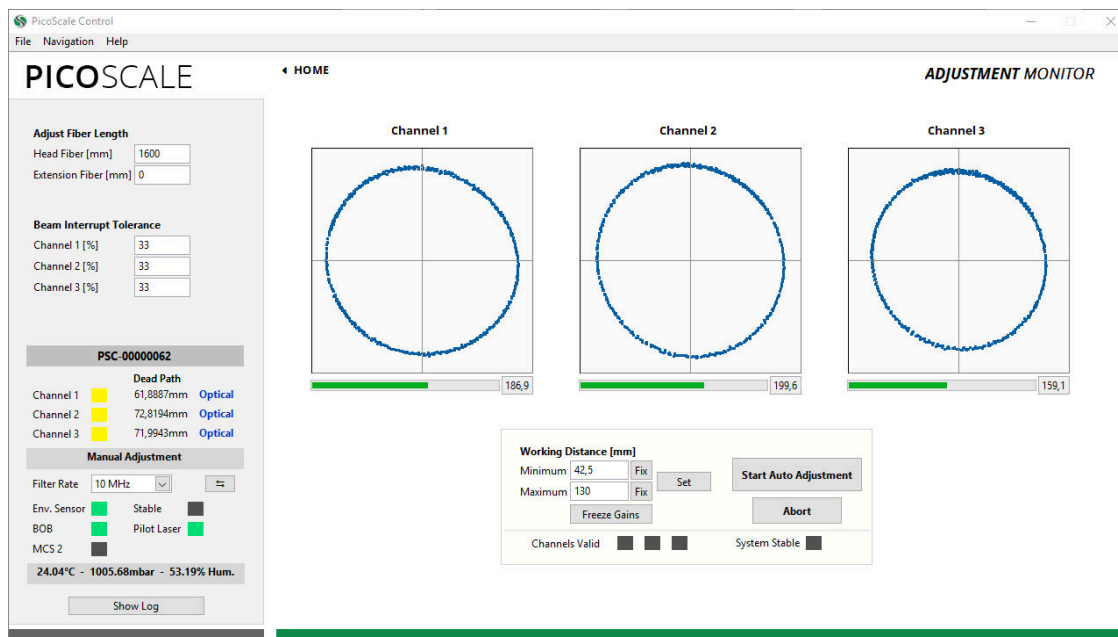Figure 7.4: System log of the **PICO**SCALE controller

7.2 Adjustment

Figure 7.5: **PICO**SCALE Adjustment Panel.

The three input channels of the **PICO**SCALE can be configured in the *Adjustment Monitor*. The goal of the adjustment is to align the interferometer heads in front of the target mirrors and optimize the signal quality. Furthermore, internal subsystems of the **PICO**SCALE device are optimized to achieve highest possible resolution and accuracy of position measurements. Note that a full-access connection has to be established to perform the adjustment procedure. Each channel can be enabled and disabled with the corresponding check box below the graphs before the manual adjustment is started. With the drop-down menu besides each check box the connected head type can be configured. The head type is written on the housing of each head and in the corresponding data sheet. For older heads, please use the standard head type C01.

On the upper left side of the GUI in figure 7.5 the fiber length can be changed. A standard sensor head is delivered with a fiber length of about 1600 mm. If additional extension fibers are used the length should be inserted in the field *Extension fiber [mm]*. Furthermore, the *beam interrupt tolerance* can be set: The **PICO**SCALE generates so-called *beam interrupt* events when the signal quality drops below a certain threshold. The **PICO**SCALE can be made more tolerant to these events by increasing the value of the *beam interrupt tolerance* (default: 33%). A value of 100% means that no beam interrupt events are produced any more.

Channel enabling/disabling and configuration of the head type must be done before the adjustment process is initiated, the beam interrupt tolerance can be set at any point.

The manual adjustment procedure is started by clicking on the *Start Manual Adjustment* button. Figure 7.5 shows the *Adjustment Monitor* with one Lissajous graph for each channel after the manual adjustment is started. Enter the expected working range (which influences the modulation amplitude) and confirm it by clicking *Set*. The more precise you enter the expected working range, the higher the accuracy of your measurement will be.

Then you have to align sensor head and target mirror with respect to each other. To rate and optimize the alignment, use the Lissajous graph and the signal quality bar.

> **NOTICE**
> The absolute number of the signal quality has no meaning. It is just a temporary indicator which helps you to optimize the current alignment. It is dependent on many factors so that it cannot be used for comparison with previous alignments with slightly different settings (working range, different channels, etc.).

When the sensor head is tilted relative to the target mirror, the shape (diameter and thickness) of the Lissajous figure as well as the signal quality change. However, during this alignment the signal amplification is actively adjusted, so that the signal amplitudes cover the whole ADC range. A very sensitive way to optimize the orientation of the measurement heads is to "freeze" the analog gains, by pressing the *Freeze Gains* button. In this case, the diameter of the corresponding Lissajous figure changes due to tilting of the sensor heads and should be maximized. (If, during this process, the Lissajous figure size exceeds the display, simply "unfreeze" and freeze the gains again.)

After the manual adjustment is done, start the automatic adjustment by clicking the *Start Auto Adjustment* button. During this phase, the channel electronics (gains, demodulation phases, etc.), as well as the internal signal processing algorithms are optimized automatically. A *Progress* bar indicates the status of the auto adjustment. The *Results* panel summarizes the results of the individual subroutines of the adjustment process. To guarantee optimal performance, the enabled channels should be valid and the system must be stable. The adjustment process can be aborted at any time, simply by deactivating the *Manual Adjust* or the *Auto Adjust* buttons.
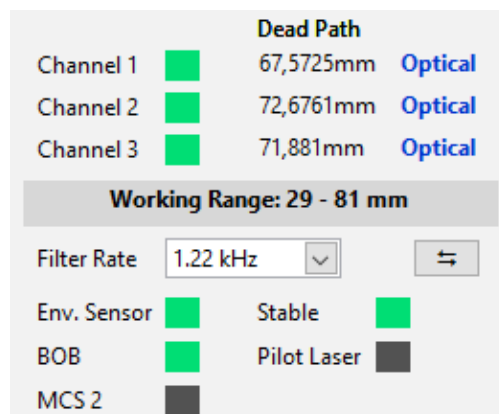

Figure 7.6: Results of the Auto Adjustment routine. All channels are valid and the laser is stable. The label *Optical* indicated that optical pathlengths are measures, i.e. environmental compensation is not active.
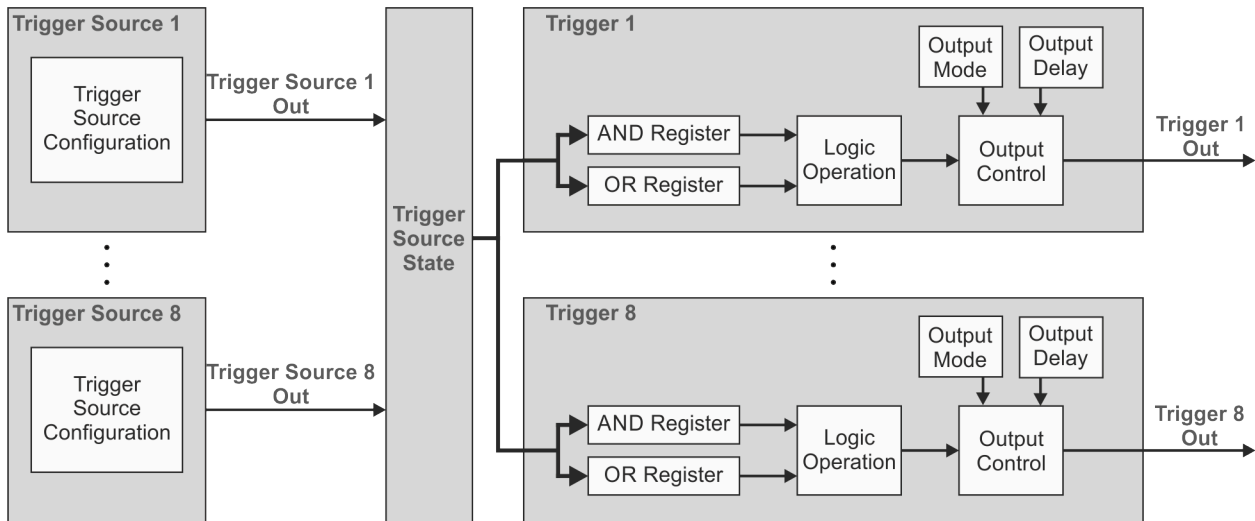
7.3 Advanced Trigger

Figure 7.7: Block Diagram of the **PICO**SCALE Trigger System.

The *Advanced Trigger System* can be purchased as an additional feature for the **PICO**SCALE system which allows to synchronize internal and external processes. Figure 7.7 shows the block diagram of the *Advanced Trigger System*. The system offers eight trigger sources (left side) which can be logically combined to up to eight actual trigger output signals (right side). These signals may be used by other internal sub systems or can be output by the GPIO interface to control and/or synchronize external devices.

Each individual trigger source has an output signal, which can be logically HIGH or LOW. All trigger source signals are stored in a trigger source state register to which all eight triggers have access. Each trigger can combine several trigger sources by logical operations (AND, OR, etc.) which allows to define very complex trigger logics. Additionally, the trigger signal can be delayed or debounced to produce stable and reliable output signals that can be logically HIGH or LOW. The following sub systems can use trigger signals:

- **Stream Generator, see section 7.6**
  - start / stop / pause the data stream
  - define the rate at which the data frames are generated
- **Digital IO Interface, see section 7.4.1**
  - output trigger signals as TTL or CMOS signals
- **Clock Generators, see section 7.5.1**
  - start / stop a clock generator
- **Counters, see section 7.5.4**
  - start / stop / increment a counter

The advanced trigger system can be configured in the *Advanced Trigger System* panel of the **PICO**SCALE Control GUI.
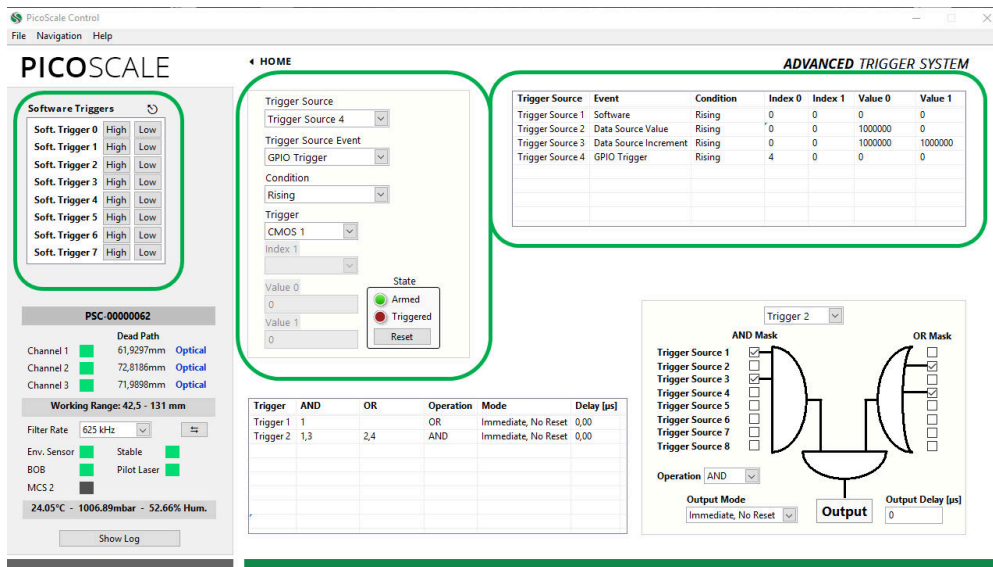
7.3.1 Trigger Source configuration

Figure 7.8: Trigger Source Configuration; highlighted by green boxes

A trigger source is a basic component in the FPGA, which may be configured to listen to specific events and react in a specific way. The configuration of a trigger source can be controlled within the *Advanced Trigger System* panel. This enables access to specific properties, which are explained in detail in the Programmer's Guide. The table on the right part of figure 7.8 presents the values of the corresponding trigger source configuration properties, thus, providing an overview of all enabled trigger sources.

In the center of figure 7.8 you can select one of the eight available trigger sources. You can then select the desired trigger source *Event*. This is the signal to which the trigger source listens to. The meaning of the other fields depends on the chosen *Event*. The GUI disables unnecessary fields and updates the names of the controls.

Trigger Event *None*

The first *Event* is **None**. This event disables a trigger source and its output will remain in the logical LOW state. All other register fields are not used and have no meaning.

Trigger Event *Software*

The **Software** event performs a state change of the trigger source when a software event is received. To generate a software event, the API offers a special trigger source property *Software Trigger*, which can be addressed using the *Property Dialog* (see section 7.9). For this event, the Index 0 register holds the *Software Trigger ID*, a number that is compared to the trigger ID given by the software event. On a match the trigger source switches to the state given by the property value.

Trigger Event *Data Source Value*

The **Data Source Value** event performs a state change of the trigger source output when a data source value passes a certain threshold or enters a certain range. Please note that not all data sources are available. The possible data sources are restricted to position, Calculation System outputs, ADCs and counters. The *Condition* menu allows to define how the selected data source value and the configured threshold(s) are evaluated. The following conditions are available which are illustrated in figure 7.9 and 7.10:

- *Single Rising*/*Single Falling*: The trigger source output is HIGH when the selected data source value passes the *Threshold* from below/above. Once the trigger source is in a logically high state, it stays high until reset.

- *Single Either*: The trigger source output is HIGH when the selected data source value passes the *Threshold* from below or above. Once the trigger source is in a logically high state, it stays high until reset.

- *Positive/Negative Level*: The trigger source is HIGH when the data source value is above the *Threshold* and is LOW when the data source value is below the *Threshold*. For the negative level it is vice versa.

- *Positive/Negative Range*: The trigger source is HIGH when the data source value is *inside* the range defined by the *Lower* and *Upper Threshold* and LOW otherwise. For the negative range it is high when the data source value is *outside* the specified range.
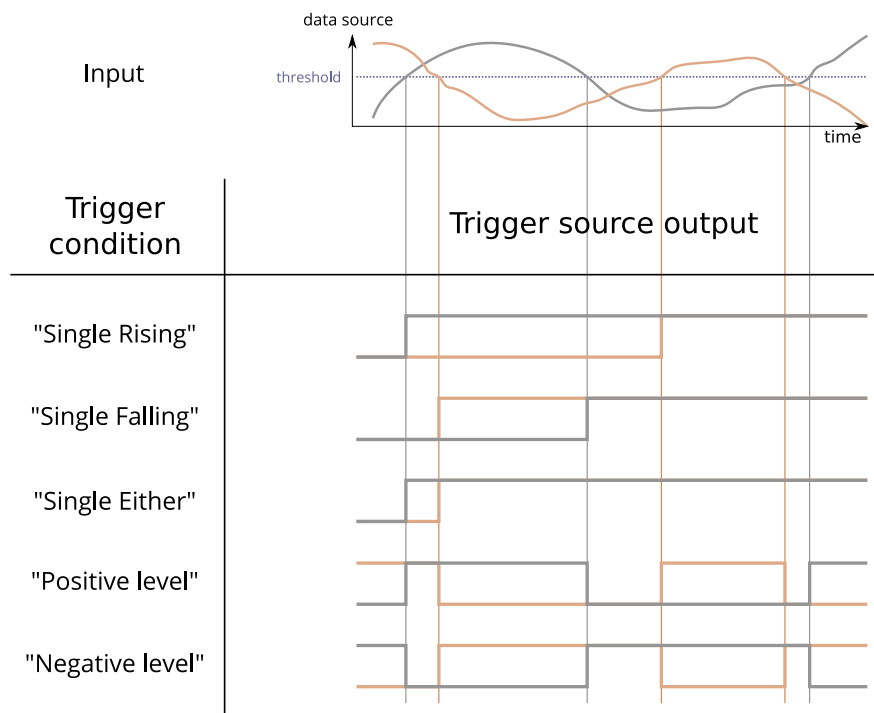

Figure 7.9: Summary of trigger conditions. Two traces of a data source are shown (position, for example) with a user defined threshold. The trigger conditions *single rising, single falling, single either, positive level* and *negative level* are illustrated.
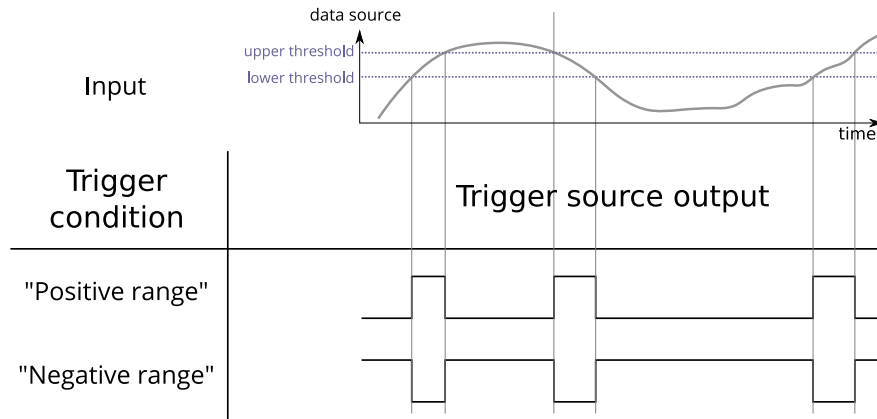
Figure 7.10: Summary of trigger conditions. The trigger conditions *positive range* and *negative range* are illustrated, which both require an upper and lower threshold to define the appropriate range.

The next field *Data Source* allows for selecting the desired data source. With the last two fields the *Thresholds* for the selected condition can be defined.

Trigger Event *Data Source Increment*

The **Data Source Increment** event generates positive pulses (a state change from LOW to HIGH and back again) on the trigger source output whenever a certain increment of a data source value is detected. A start *Threshold* can be defined and after the data source passes this value, the threshold register is incremented by the defined *Increment* value. Please note, that not all data sources are available. The *Condition* menu allows to define how the selected data source value and the configured threshold/increment tuple are compared to each other. The following conditions are available:

- *Single Rising*/*Single Falling*: A pulse is generated when the selected data source value passes the *Threshold* from below/above. When this happens the *Threshold* is incremented or decremented by the *Increment* value.

The next two fields, *Channel* and *Source*, allow for selecting the desired data source. Finally, you can define the start *Threshold* and the *Increment*.

Trigger Event *GPIO Trigger*

The **GPIO Trigger** event listens to a specific GPIO input pin. To use a GPIO pin as trigger input signal, the corresponding pin has to be defined as input, cf. section 7.4. The *Condition* menu allows to define how the trigger source reacts on the selected input pin. The following conditions are available:

- *Single Rising*/*Single Falling*: The trigger source output is HIGH when a rising/falling edge is detected on the selected input pin. Once the trigger source is in a logically high state, it stays high until reset.

- *Single Either*: The trigger source output is HIGH when a rising or a falling edge is detected on the selected input pin. Once the trigger source is in a logically high state, it stays high until reset.

- *Positive Level*, *Negative Level*: The level or the inverted level of the selected input pin is forwarded to the trigger source output. In this case the state of the trigger source depends on the level of the input pin.

The next field *Channel* allows for selecting the desired input pin. The pin labels are in accordance with the pin labels of the **PICO**SCALE Breakout-Box (BOB).

Trigger Event *External Trigger*

The *Event* **External Trigger** listens to the external trigger pin that is on the front panel of the **PICO**SCALE Controller housing. The *Condition* menu allows to define how the trigger source reacts on the External trigger input pin. The following conditions are available:

- *Single Rising*/*Single Falling*: The trigger source output is HIGH when a rising/falling edge is detected on the input pin. Once the trigger source is in a logically high state, it stays high until reset.

- *Single Either*: The trigger source output is HIGH when a rising or a falling edge is detected on the input pin. Once the trigger source is in a logically high state, it stays high until reset.

- *Positive Level*, *Negative Level*: The level or the inverted level of the input pin is forwarded to the trigger source output, respectively. In this case the state of the trigger source depends on the level of the input pin.

All other fields are not used and have no meaning.

Trigger Event *Internal Event*

The last *Event*, **Internal Event**, reacts to signals that are generated when internal events occur, for example a *Beam interrupt* event. The *Condition* menu defines how the trigger source reacts on the selected event signal. The following conditions are available:

- *Single Rising*/*Single Single Falling*: The trigger source output is HIGH when a rising/falling is detected on the input pin. Once the trigger source is in a logically high state, it stays high until reset.

- *Single Either*: The trigger source output is HIGH when a rising or a falling edge is detected on the input pin. Once the trigger source is in a logically high state, it stays high until reset.

- *Positive Level*, *Negative Level*: The level or the inverted level of the input pin is forwarded to the trigger source output, respectively. In this case the state of the trigger source depends on the level of the input pin.

The next two fields, *Event* and *Channel*, allow for selecting the desired internal event and the corresponding channel. All other fields are not used and have no meaning.

Trigger Reset

The two LEDs indicate the *State* of the trigger source. As explained above, the trigger source remains HIGH when the selected condition is *Rising*, *Falling* or *Either* until it is reset. This means that the trigger source is inactive and ignores further input changes. In this case the *State* LEDs show *Triggered*. If the trigger source is ready and active, the LEDs show *Armed*.

If the trigger source is in the (inactive) *Triggered* state, the button *Reset* switches the trigger source to logically LOW and activates the trigger again. The *State* LEDs will switch to *Armed*.
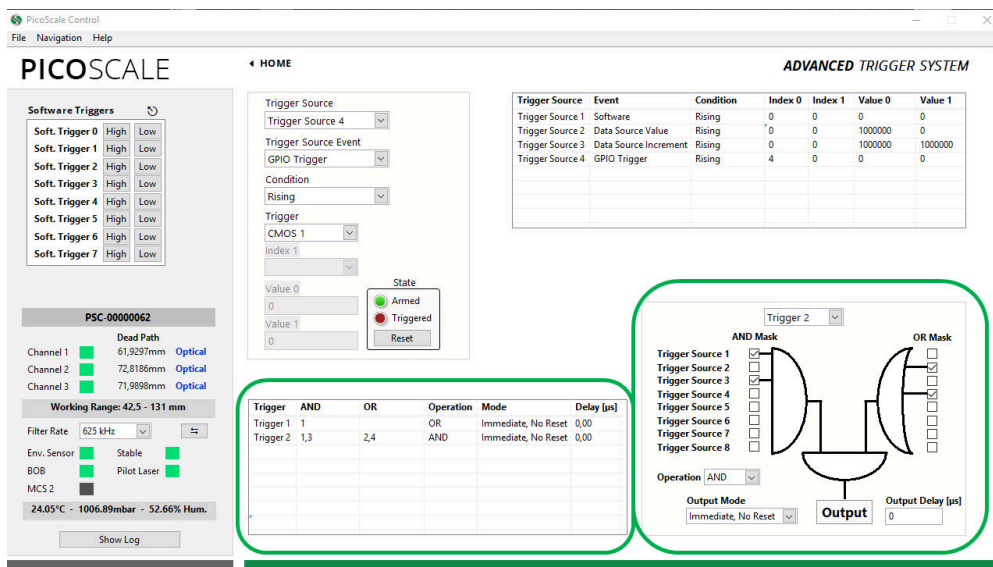
7.3.2 Trigger configuration

Figure 7.11: Trigger Configuration; highlighted by green boxes

Triggers logically combine the outputs of one or more trigger sources to generate an actual trigger output signal. Each trigger has a set of registers, like *AND Mask*, *OR Mask*, *Logic Operation*, as well as *Output Mode* and *Output Delay*. The **PICO**SCALE GUI allows to configure these registers. The *Trigger Index* drop-down menu in the lower right corner of figure 7.11 allows to select a trigger.

For the trigger configuration, an *AND Mask* and an *OR Mask* are available, where you can combine all trigger sources with logical ANDs or ORs, respectively. The outputs of these two masks are logically connected by another *Logic Operation*, to form the trigger output signal. The following *Logic Operations* are available:

- **Disabled** Deactivates the selected trigger. The GUI automatically removes the trigger from the *Active Trigger Configuration* tabular.

- **OR:** The output becomes LOW if both inputs are LOW. In all other cases, the output is HIGH.

- **NOR** or **NOT OR** The output becomes HIGH if both inputs are LOW. In all other cases, the output is LOW.

- **AND** The output becomes HIGH if both inputs are HIGH. In all other cases, the output is LOW.

- **NAND** or **NOT AND** The output becomes LOW if both inputs are HIGH. In all other cases, the output is HIGH.

- **XOR** The output becomes LOW if both inputs are simultaneously HIGH or simultaneously LOW. In all other cases, the output is HIGH.

- **NXOR** or **NOT XOR** The output becomes HIGH if both inputs are simultaneously HIGH or simultaneously LOW. In all other cases, the output is LOW.

! NOTICE

If you simply want to pipe through a trigger source as a trigger output signal, select the corresponding trigger source in the AND Mask, do not select anything in the OR Mask (so that its output is always LOW) and combine the two masks by an OR operation in the *Logic Operation*.

Finally, you have to configure the *Output Mode* and *Output Delay* of your trigger signal. Some trigger sources simply create short pulses or the trigger condition may be subject to high frequency state changes. In order to debounce or widen the pulses you can select an appropriate *Output Mode* as well as an *Output Delay*. The **PICO**SCALE offers four different *Output Modes*, which are also illustrated in figure 7.12:

- **Immediate No Reset:** In this mode the output control logic forwards a change of the trigger state immediately and the state is kept stable for the configured delay.

- **Immediate Reset:** In this mode the output control logic forwards a change of the trigger state immediately and the state is kept stable for the configured delay. A state change during this delay resets the delay counter.

- **Delayed No Reset:** In this mode the output control logic starts a delay counter when the trigger state changes. State changes during this delay are ignored. At the end of the delay the current state is forwarded.

- **Delayed Reset:** In this mode the output control logic starts a delay counter when the trigger state changes. State changes during this delay are ignored, but cause the delay counter to be reset. At the end of the delay the current state is forwarded.

Note that the output mode only takes effect when a non-zero output delay is configured. When the output delay is set to zero (default), the resulting trigger signal is identical to the input signal.

The output modes are divided into two categories, *Immediate* and *Delayed*. *Immediate* performs a state change of the trigger output immediately after a state change of the input signal is recorded. *Delayed* on the other hand keeps the current trigger state and waits for a certain time until the trigger output reacts on an input signal state change.

The subcategories *Reset* and *No Reset* determine how the entered *Output Delay* is taken into account by the trigger system. Once a state change of the input signal is recorded, a delay counter is started. In the *No Reset* case this counter runs independently of the input signal, thus deactivating the trigger output for a fixed time. In case of *Reset*, the delay counter is restarted every time the input signal changes its state. Thus, this mode guarantees that the trigger output remains in its current state until the input signal is stable for the defined *Output Delay* time.
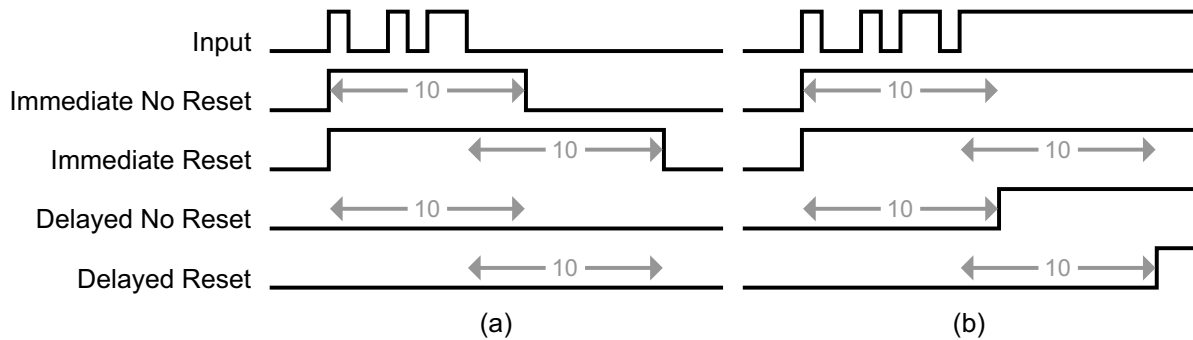
Figure 7.12: Trigger Output Control Behavior (output delay = 10). The input traces are the result of the configured logic operation of the trigger and the eight traces below show the resulting trigger signal for the four output modes. The first input trace (a) shows some short pulses (e.g. a steady low level with some noise) while the second trace (b) shows a noisy transition of the input signal from low to high (similar to a trace of a mechanical button when pressed).

In the middle of figure 7.11 the *Active Trigger Configuration* table provides an overview of the configured triggers. In this table the first column displays the name of the active triggers. The next two columns show the state of the eight *AND* and *OR* masks. The last three columns display the chosen logic *Operation*, the output *Mode* and the output *Delay*.

7.4 Interfaces

The *Interfaces* panel allows to configure the GPIO interface of the **PICO**SCALE system. It groups the *Digital IO*, *AquadB* and the *Digital-to-Analog (DAC)* sub-panels.

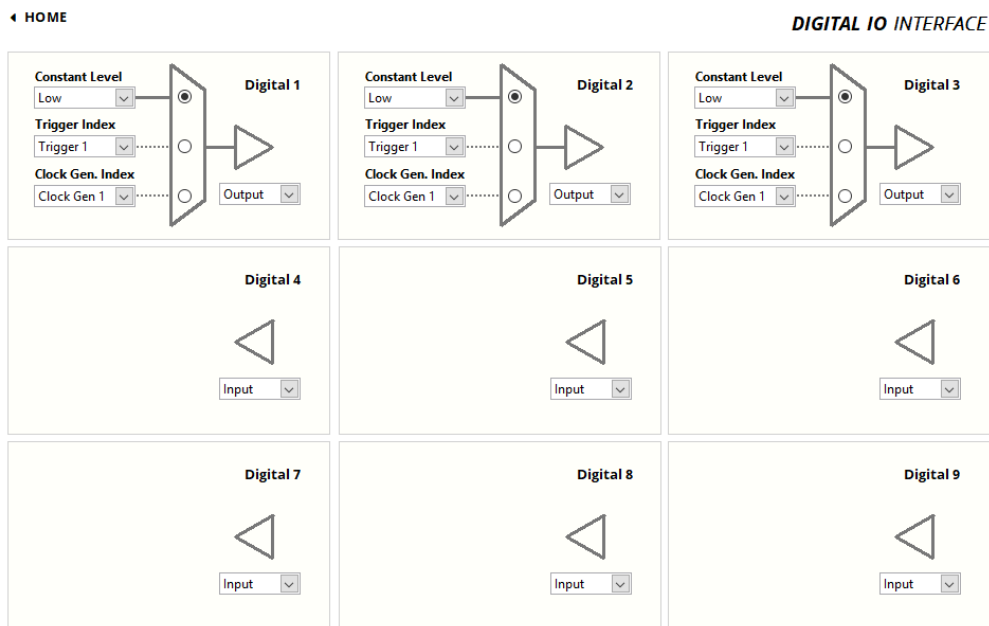### 7.4.1 Digital IO interface configuration

Figure 7.13: Configuration Menu of the Digital IO Interface.

The **PICO**SCALE offers nine digital IO pins, which are directly connected to the FPGA controller. The IO pins *Digital 1* to *Digital 4* are TTL ports and *Digital 5* to *Digital 9* are CMOS ports. They have a voltage range of 0 to 3.3 V[1]. Each pin can be configured as input or as output pin and is accessible via the D-Sub 44HD connector at the system back side or more conveniently via the *Breakout-Box* (BOB). When the *Digital 1* to *Digital 4* pins are accessed via the Breakout-Box (BOB), their voltage range is raised to 0 to 5V.

Figure 7.13 shows the *Digital IO Interface Configuration* panel. Each pin can be configured individually. *Digital 1* to *Digital 3* are configured as *Output* ports, *Digital 4* to *Digital 9* are *Input* ports in this figure.

The arrangement of the individual menus is equal to the pin arrangement of the **PICO**SCALE Breakout-Box. Each pin configuration has a drop-down menu in the bottom right corner, with which the direction of the corresponding pin can be configured. The triangle in front of each LED indicates whether the pin is configured as input or output.

On the left hand side of each panel three drop-down menus are available:

- **Constant Level** The output can be set to either logically HIGH or LOW.

---

[1] In **PICO**SCALE Controllers with the product codes PSC-CTRL-V1.0-TAB and PSC-CTRL-V1.1-TAB the signals GPIO.TTL* have a 5V TTL level

- **Trigger Index** A trigger (that has been defined in the *Advanced Trigger* module) controls the output of the pin. In the drop-down menu the respective trigger index can be chosen.

- **Clock Gen. Index** A clock as defined in the *Clock Generators* configuration controls the output. In the corresponding menu it's index can be chosen.

The switch to the right hand side of the three menus finally defines, if the configured manual state, the trigger or the clock generator output controls the pin. Note, that the mentioned options are pin output options and only have effect, if the pin is configured as output pin. If a pin is configured as output, e.g. *Digital 1*, the switch is connected to the triangle. While if a pin is configured as input, e.g. *Digital 4*, the drop-down menus are not visible.

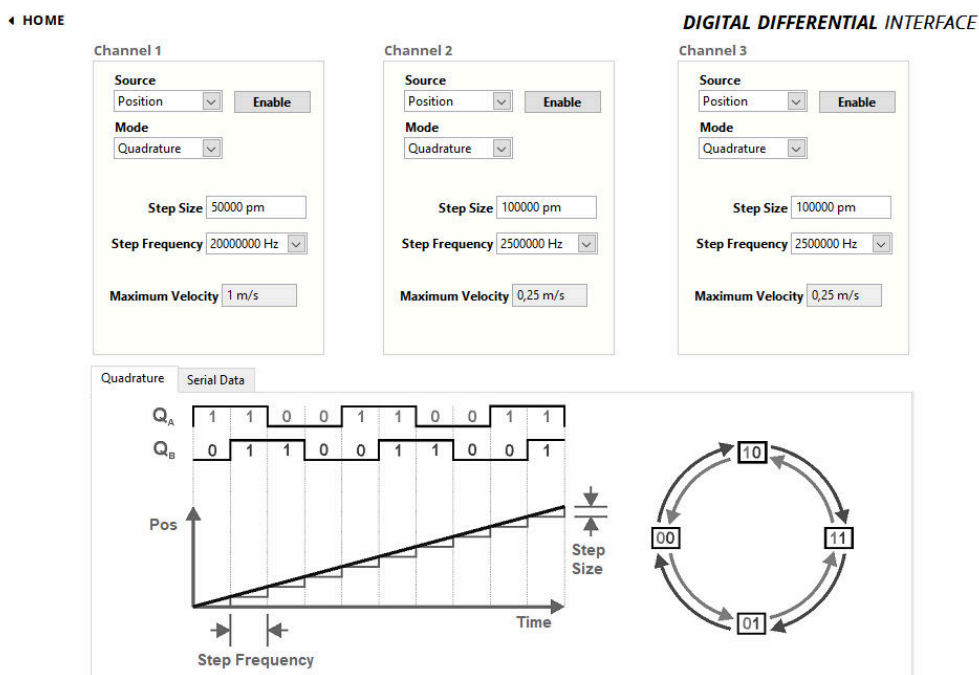### 7.4.2 Digital Differential Interface (DDI) configuration

Figure 7.14: Configuration Menu of the Quadrature Interface.

The **PICO**SCALE offers three DDI outputs, which are accessible via the D-Sub 44HD connector at the system's back plane or more conveniently via the *Breakout-Box* (BOB). Each of these outputs can be configured as a *Quadrature* (AquadB) or a *Serial Data* interface.

The source of each channel can be chosen by the *Source* drop-down list. Available are the options *Position*, which provides position data, and *CalcSys* that maps the output of the calculation system. In the top right corner of each menu, an *Enable* button allows to activate the output.

With the drop-down list *Mode* the *Quadrature* or the *Serial Data* option is selected.

Below the configuration panels the principle of data representation is explained and the relevant properties are defined. Note, that since the **PICO**SCALE only measures relative position changes, no AquadB index signal is available.

Quadrature output (AquadB)

For each quadrature output a configuration menu is available. It allows the configuration of the following paramters:

- **Step Size** The step size is entered in picometer (pm). Values between 1 pm and 1 cm are accepted.

- **Step Frequency**. The drop-down menu allows to change the step frequency of the quadrature interface with preset values ranging from 100kHz up to 20MHz.

The maximum target velocity is calculated by the **PICO**SCALE according to the configuration of the AquadB channel and displayed underneath the *Step Frequency* field.

Serial data output (SD)

For each serial data output the configuration menu allows the configuration of the following parameters:

- **Clock Frequency** defines the data rate of the serial signal in Hz. It can be configured from 100kHz up to 10MHz.

- **Clock Pause Delay** defines a delay between two data words and is counted in clock cycles.

- **Data Idle Priority** defines the idle state of the data lines. It can be either *low* or *high*.

- **Clock Mode** defines the clock and data modes as described in chapter 5.3.1.

- **Bitwidth** defines the *Bitwidth* of a data word and the *Shift*.

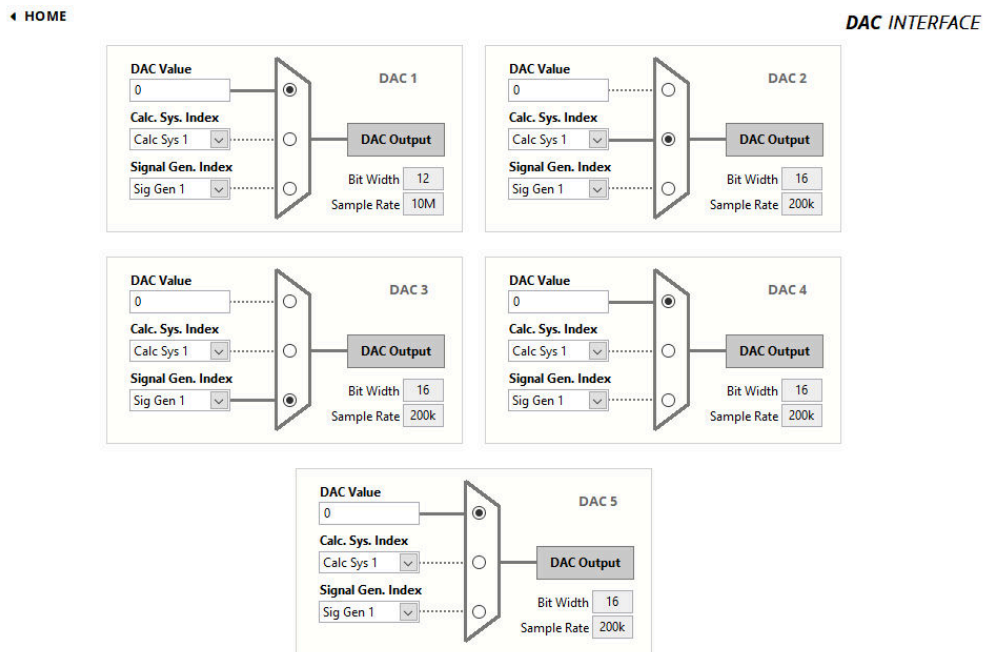### 7.4.3 DAC interface configuration

Figure 7.15: Configuration Menu of the DAC Interface.

The **PICO**SCALE offers five DAC outputs that can be configured in the *DAC Interface* panel. DAC 1 is a fast 10 MHz output channel with 12 bit resolution, DAC 2–5 have 16 bit resolution but their sample rate is limited to 200 kHz. The corresponding bit widths and sample rates are displayed in the bottom right corner of each configuration panel.

Each DAC interface can be controlled by one of the following options, that can be selected via the switch next to the drop-down menus:

- **DAC Value** A constant output with the specified value is generated. The range is [-1,1] (float64) corresponding to a ±10 Volt output.

- **Calc Sys Index Select** The result of the specified calculation system is mapped to the DAC.

- **Sig Gen Index Select** The signal generator with the specified index is mapped to the DAC.

7.5 Modules

The **PICO**SCALE modules add much more versatility to your applications. These modules are the *Clock Generator* module, the *Arbitrary Signal Generator* module, the *Calculation System* module and the *Counter* module.
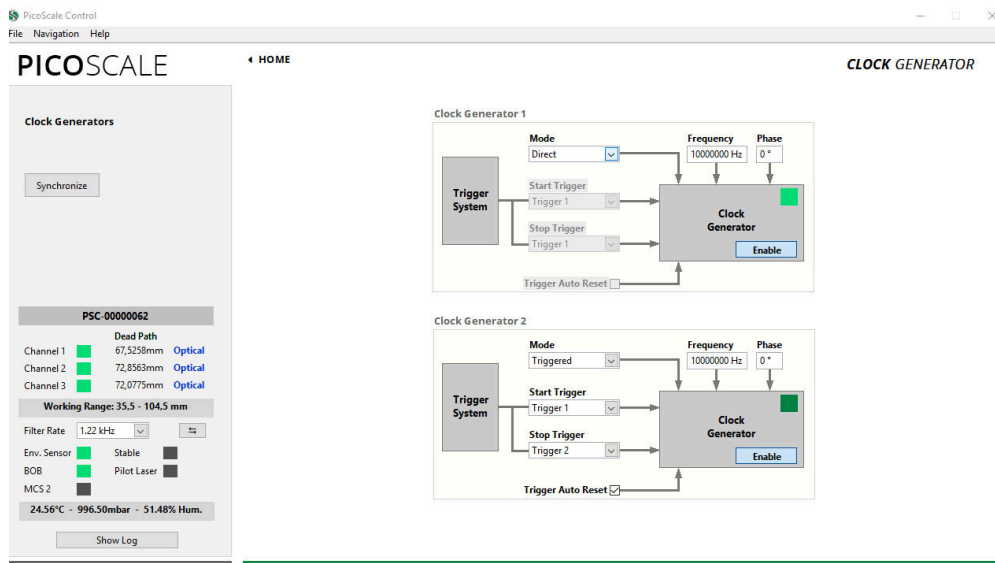
7.5.1 Clock Generator

Figure 7.16: Configuration Menu of the Clock Generators.

The **PICO**SCALE offers two digital clock generators, which can output frequencies from 1 Hz to 10 MHz. A clock generator can be used to simply output a clock via one of the GPIO pins, or it can be used inside the advanced trigger system to synchronize internal data sources with external processes, for example. In these applications, the **PICO**SCALE generates the master clock.

All clock generators are derived from the same master clock and can thus be synchronized. As depicted in figure 7.16, each clock generator can be configured by a *Frequency* and a *Phase Shift*. Enabling of each clock generator is done by the *Enable* button in the center of the each *Clock Generator*. Both generators can be synchronized to each other with a defined phase shift by clicking the *Synchronize* button on the left side of the window.

Continuous output of a configured clock is realized in the *Direct* mode of the clock generator. However, when you want to control external devices by the **PICO**SCALE or vice versa, it is helpful to start and/or stop the clock generators once appropriate trigger conditions are given. For this, the *Mode* of the clock generator must be set to *Triggered* and the the corresponding start and stop trigger indices defined (cf. figure 7.16). The start and stop triggers are selected in the two drop-down menus on the left side of each clock generator configuration panel. The triggers can be configured in the respective menu of the *Advanced Trigger* panel. If the *Auto Reset Mode* is enabled, the clock generator will listen for another start trigger after receiving a stop trigger. Otherwise the clock generator can only be restarted by disabling and enabling it again manually. The auto reset mode has no meaning in the direct clock generator mode.

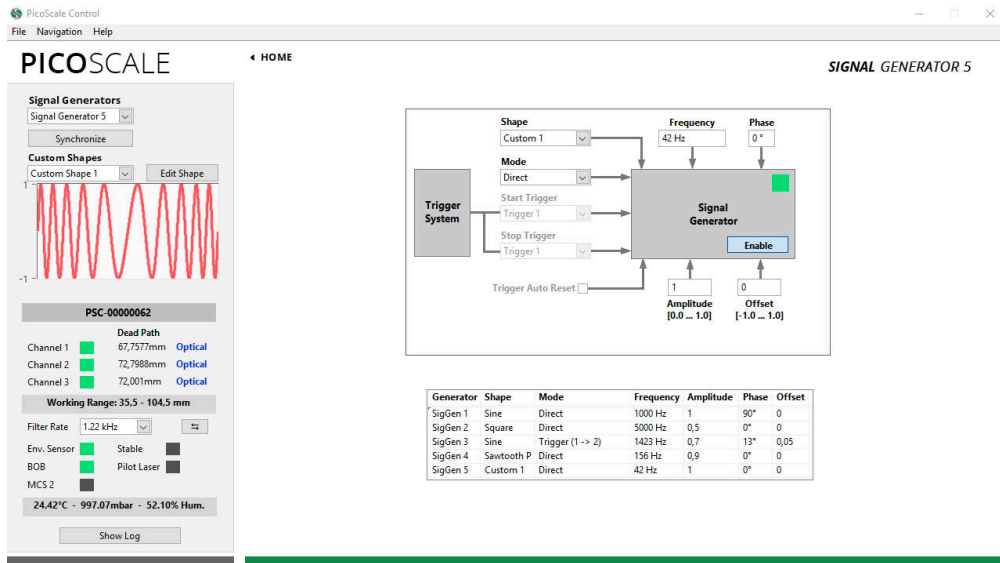## 7.5.2 Arbitrary Signal Generator

Figure 7.17: Configuration Menu of the Arbitrary Signal Generators. In this example a frequency modulation was uploaded as customized signal shape.

The **PICO**SCALE offers basic signal generator functionality with sine, square and sawtooth shapes. Additionally, custom shapes can be uploaded as CSV files. In the configuration panel, see fig. 7.17, you can configure up to five signals (corresponding to five DAC interfaces). For each signal generator you can choose sine, square, sawtooth (P: slow positive ramp, N: slow negative ramp) or custom shapes in the *Shape* drop-down menu.

The frequency of the signals can be chosen between 1 mHz and 2.5 MHz. Note, that only DAC1 has a high 10 MHz sample rate and may be used to output fast signals. DAC2–DAC5 are limited to 200 kHz sample rate. The amplitude can be set in a range between 0 and 1 and the offset of the signal can individually be set in a range between -1 and 1, where -1 corresponds to −10 V and 1 to 10 V. For example, a square signal with values between 0 and 5 Volt (i.e. TTL standard) can be generated with the setting: shape *Square*, amplitude 0.25, offset 0.25.

When more than one signal generator is used, the signals can be synchronized with each other by clicking the *Synchronize* button in the upper left part of the *Signal Generator* panel.

In the *Custom Shapes* panel, up to five custom shapes can be uploaded from CSV files. The files must consist of 2^{12}=4096 float numbers (double, 64 bit) which represent the amplitude of the signal at each point. Thus the numbers have to be in the range [-1,1]. (Decimal sign is "." and the individual entries have to be separated by a line break.) The shape of the uploaded signal is displayed in the graph. The *Edit Shape* button opens the *Custom Shape Editor* which allows to define a custom signal shape by entering a formula or by uploading it from a CSV file.
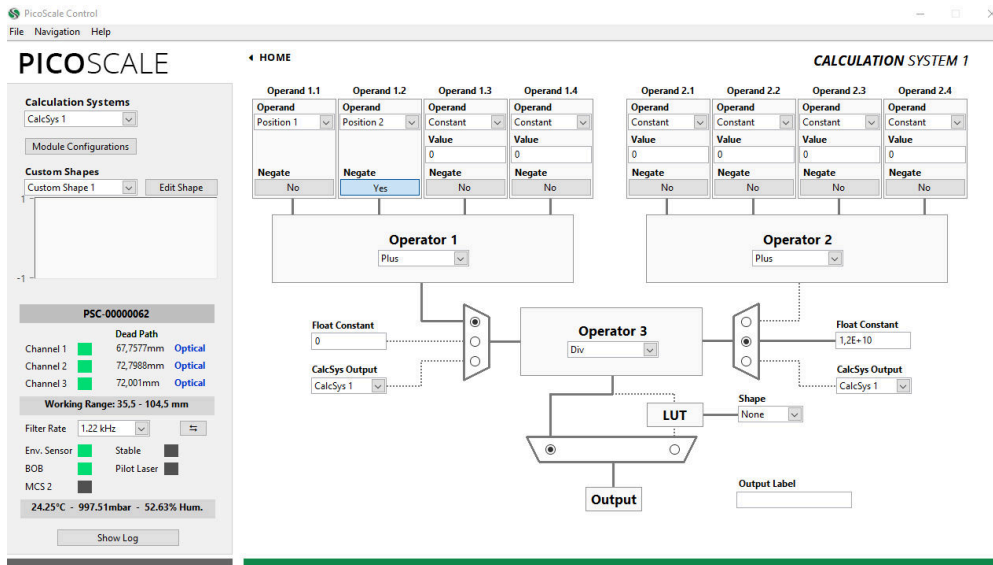
7.5.3 Calculation System

Figure 7.18: Configuration Menu of the Calculation System.

Within the *Calculation System* you can perform basic calculations with data sources. Up to eight calculation systems can be configured with the *Calculation Systems* drop-down menu in the upper left part of the window.. First, you can define up to four operands (1.1–1.4). Each operand can be a constant, a position/velocity/acceleration value from one of the three **PICO**SCALE channels, an ADC value, a data source value from the environmental module (temperature, pressure or humidity), signal generator outputs or a counter value. Then, you can sum up the four channels or the minimum or maximum value can be calculated as defined in the grey *Operator 1* box. If, for instance, a subtraction is required, the *Negate Output* button can be activated in order to multiply an operand by -1 before performing the summation. The exact same operations can be performed with a second branch of data by defining operands 2.1–2.4 and *Operator 2*. In the third stage, the results of *Operator 1* and *Operator 2* can be processed with *Operator 3*, resulting in a *Calc Sys Result*. *Operator 3* allows summation, subtraction, multiplication, division or Max/Min operation. Alternatively, the inputs of *Operator 3* can be set to a float constant or the *Calc Sys Result* of another calculation system.

In the exemplary operation as shown in figure 7.18 the calculation is set up to give

$$Calc\,Sys\,Result = \frac{Position\,1 - Position\,2}{12000000000}\,.$$

By default, the result is simply forwarded to the 64 bit *Calc Sys Output*. However, it is possible to map the result to a specific value defined by a lookup-table (LUT). Note that in this case, the calculation system result has to be in the range of [-1,1]. Results outside this range will be truncated. The lookup-table needs to have 12 bit resolution (and thus has a length of 2^{12}=4096 points). The result is interpolated based on those 4096 points to again give a 64 bit resolution. User defined LUTs can be uploaded as CSV files in the *Custom Shapes* panel. (Decimal sign is "." and the 4096 individual entries have to be separated by a line break.) Once a calculation system is configured, it can be stored in configuration slots for later usage by using the *Module Configurations* button.
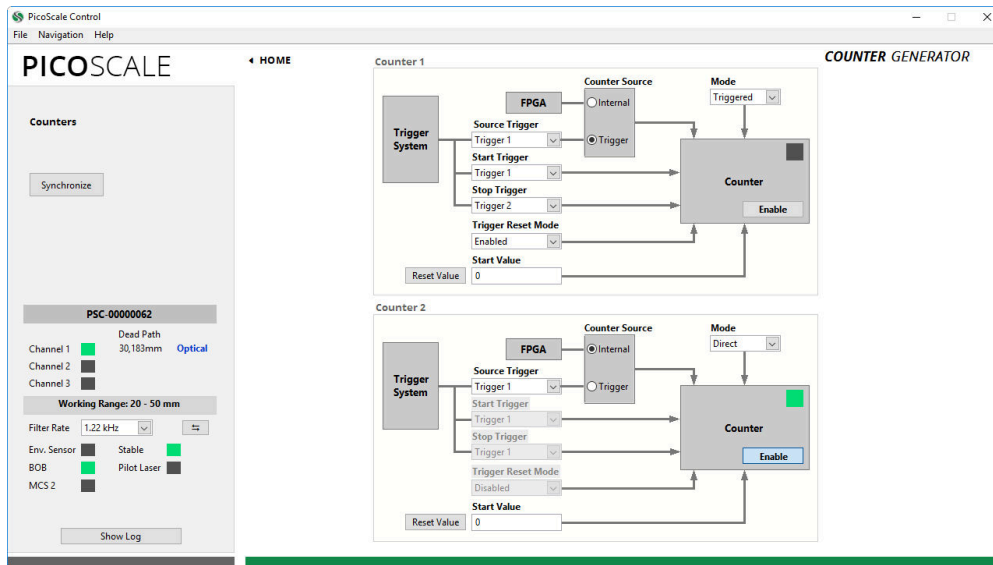
7.5.4 Counter

Figure 7.19: Configuration Menu of the Counters.

The **PICO**SCALE offers two *Counters* that may be used as a timer (counting FPGA clock cycles) or as an event counter of trigger events, see fig. 7.19. The counter trigger index can be set to one of the eight trigger indices that can be configured within the *Advanced Trigger* module. If the *Counter Mode* is set to *Direct*, the Counter simply counts when it is activated by the *Enable CNT* button in the *Counter Control* panel. The *Synchronize* button in the upper left of the window enables both counters simultaneously.

In the *Triggered* counter mode the counting starts in case of a *Start Trigger* event and stops in case of a *Stop Trigger* event. Both can be selected on the left hand side of the configuration panel. In the selection of the *Trigger Reset Mode*, there are three options:

- **Disabled** Counting starts at the pre-defined *Start Value* at a *Start Trigger* event and stops at a *Stop Trigger* event. Restart of the counter can only be done by disabling and enabling the counter.

- **Enabled** Counting starts at the pre-defined *Start Value* at a *Start Trigger* event and stops at a *Stop Trigger* event. Another *Start Trigger* event, starts counting again from the counter value stored from the preceding counting period.

- **Reset Value** Counting starts at the predefined *Start Value* at a *Start Trigger* event and stops at a *Stop Trigger* event. Another *Start Trigger* event, starts the counting again from the *Start Value*, thus resets the preceding value.

The LED in the *Counter* panel indicates if a counter is currently running (LED green), off (LED off) or armed (LED yellow). An armed counter means that the counter is waiting for a start trigger event. The *Reset Value* button resets the counter to the corresponding start value.
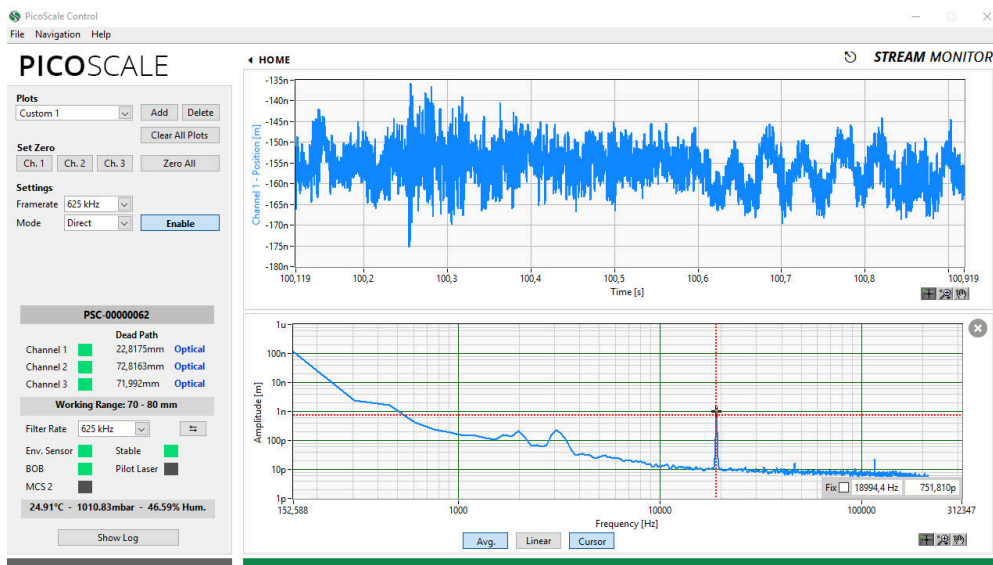
7.6 Streaming Monitor

Figure 7.20: Stream View Panel with two active streams.

For continuous data extraction from the **PICO**SCALE system, data frames can be configured and afterwards streamed to the user PC. In the **PICO**SCALE GUI the streaming interface can be controlled and used within the *Stream Monitor* panel. Each panel can be undocked using the small symbol next to the "**STREAM**MONITOR" headline so that you may move it to a different screen, for example.
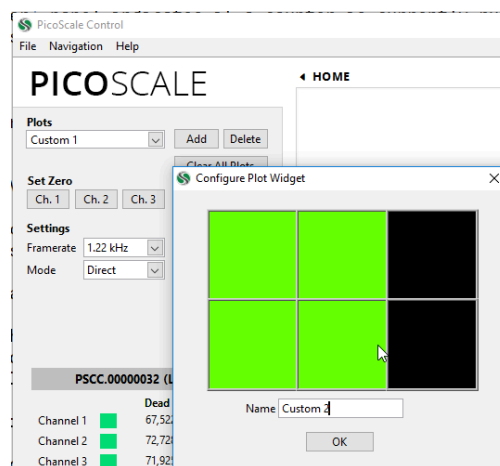
7.6.1 Configure data receiver layout

Figure 7.21: Setting up a new data receiver layout.

PICOSCALE Control allows to define a great variety of different plot layouts. When clicking the *Add* button a new windows opens up and by sweeping over the desired pattern you can define a

new panel. The more tiles you select, the smaller the individual plots will be as the pattern will be scaled to the window. You may also want to name the new panel appropriately.

7.6.2 Setting up a data receiver

Each empty plot panel contains a *Configure* button that opens a *Receiver Settings* window shown in figure 7.22.
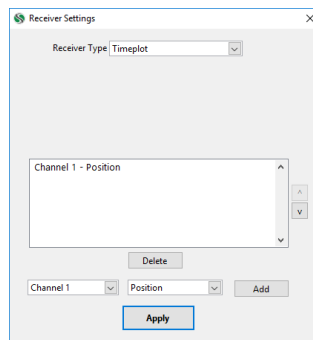

Figure 7.22: Plot configuration.

The drop-down menu *Receiver Type* allows to select the different data streams that can be processed and displayed. There are several types of data output possible:

- **Timeplot** A single plot window is shown plotting the data source(s) on the y axis over time on the x axis.

- **Timeplot (Stacked)** Several timeplots (one per data source) are stacked over each other.

- **XY Graph** The XY graph requires two inputs. The first stream is used for the x axis and the second stream for the y axis. A Lissajous figure can be plotted using the data sources Sw and S2w.

- **Numeric** A numeric output of the data stream.

- **FFT (Power Spectrum)** The power spectrum (**PS**) of one data source is calculated. You may change to linear scaling (taking the square-root) of the power spectrum to display the amplitude spectrum (**AS**). Changing between PS and AS can be done be right-clicking into the plot and selecting the appropriate scaling in the *Spectrum Scaling* selector. Units: If you, for example, calculate the PS of a *position* data source, the unit will be m^2. If you calculate the AS of a *position* data source, the unit will be m.

- **FFT (Power Spectral Density)** The power spectral density (**PSD**) of one data source is calculated, which is the power spectrum scaled by the noise equivalent bandwidth. The user may change to linear scaling (taking the square-root) of the power spectral to display the amplitude spectral density (**ASD**). Changing between PS and AS can be done be right-clicking into the plot and selecting the appropriate scaling in the *Spectrum Scaling* selector. Units: If you, for example, calculate the PSD of a *position* data source, the unit will be m^2/Hz. If you calculate the ASD of a *position* data source, the unit will be m/sqrtHz.

- **File** The data stream is directed to a file. The data are stored in binary format but using the included *Data Reader* you can convert them to *.csv files, see section 7.6.5. A header file is stored as well containing information on frame rate and a time stamp. If you stop and start the stream several times, this information is also stored in this file and you can isolate the data block later.

The white text box in the middle of the *Receiver Settings* window shows the active data sources for this plot. Sources can be added and deleted using the appropriate buttons. The drop-down menus below the text box allow to select the different channels and data types.

The available data sources have different data types which are summarized in table 7.1.

Data source	Data type	Size [bit]
Position	int48	48
Velocity	int64	64
Acceleration	int64	64
Sw Raw	uint16	16
S2w Raw	uint16	16
Sw	uint16	16
S2w	uint16	16
Counter 1–2	uint48	48
Env Sensor Temperature	int32	32
Env Sensor Humidity	int32	32
Env Sensor Pressure	int32	32
GPIO ADC1–3	uint16	16
Calculation System 1–3	float32	32

Table 7.1: Overview of all data sources and their respective data types and sizes.

After selecting the *Receiver Type* and adding one or more data sources, the plot window is configured using the *Apply* button. A plot is closed using the cross in the upper right corner of the window.

7.6.3 Manipulate the data

The *Clear all Plots* button allows to clear the history of all active time plots simultaneously. For most applications it is useful to zero the interferometer positions. This is achieved by clicking the Set Zero *Ch1*, *Ch2* and *Ch3* buttons. To zero all channels simultaneously the *Zero All* button is used.

7.6.4 Configure the data stream

In the *Settings* region the *Frame Rate* drop-down menu changes the streaming frame rate to optimize the data visualization corresponding to the experimental needs. You may choose data rates

ranging from about 1 Hz to 10 MHz. The possible frame rates are dependent on the selected data sources and the performance of your PC and network. Depending on the active data sources the system automatically determines the maximum frame rate and corrects the displayed value in the *Frame Rate* menu. You can also select triggers as frame rates so that you can use external clocks for data sampling.

The *Mode* menu allows either *Direct* or *Triggered* streaming. In case of *Triggered* streaming the *Start* and *Stop* triggers can be selected. After the stream is stopped by a corresponding trigger, the stream generator in the **PICO**SCALE FPGA still sends a certain amount of data frames, specified by the *Post Frame Count* value. After receiving a stop trigger the stream generator is disabled and needs to be enabled again, if further stream data should be recorded. Thus after receiving a stop trigger, a subsequent start trigger event does **not** activate the data stream again. However, sometimes this is necessary. With the *Reset on Stop* function the stream generator can be automatically reactivated/armed, after a stop trigger was received and the corresponding post frames were acquired.

The streaming is started and stopped with the *Enable* button.

With the drop-down menu *Filter Rate*, in the **PICO**SCALE status window, a low-pass filter can be selected, used to filter the data inside the FPGA before transmitting it. The button to the right side of the *Filter Rate* changes the drop-down menu to the corresponding *Cutoff Frequency*. The *Filter Rate* and *Frame Rate* options should be set carefully to avoid aliasing. The system indicates potential aliasing by a red logo on-top of the *Frame Rate* menu. By clicking on this logo, the *Frame Rate* is automatically adjusted to meet the *Filter Rate*.
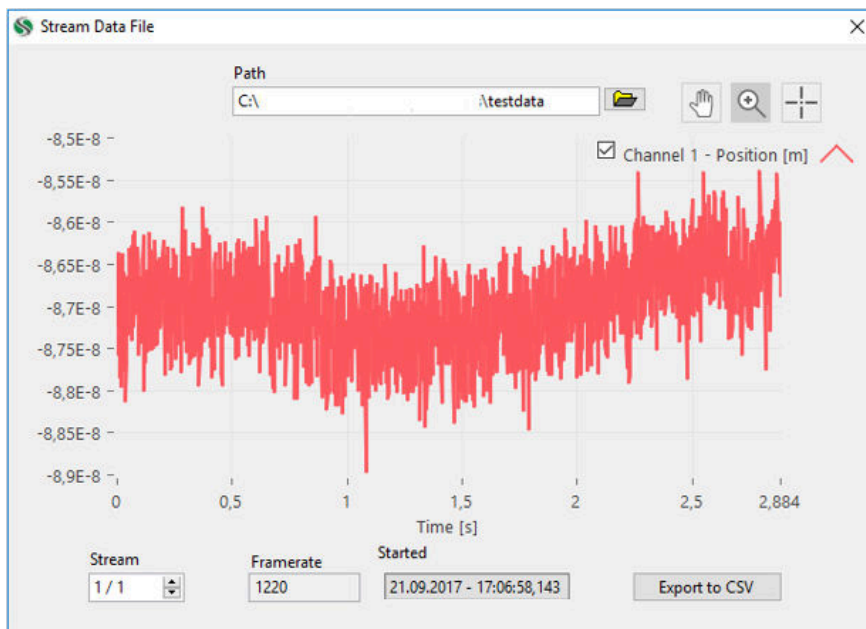
7.6.5 PicoScale Data Reader

Figure 7.23: **PICO**SCALE Data Reader. A data file has been loaded and the data are shown. Important information on frame rate and a time stamp are also given.

The data reader can process the files you have streamed to your hard disk. As the data are stored in binary format you may want to convert them to human-readable CSV files. Therefore, navigate to the Data Reader via *File → Read Stream Data File*. Here, you can select the desired header file which contains the necessary information on frame rates etc. By clicking the *Export to CSV* button you can store the data in a human-readable file that can be used for further data processing.
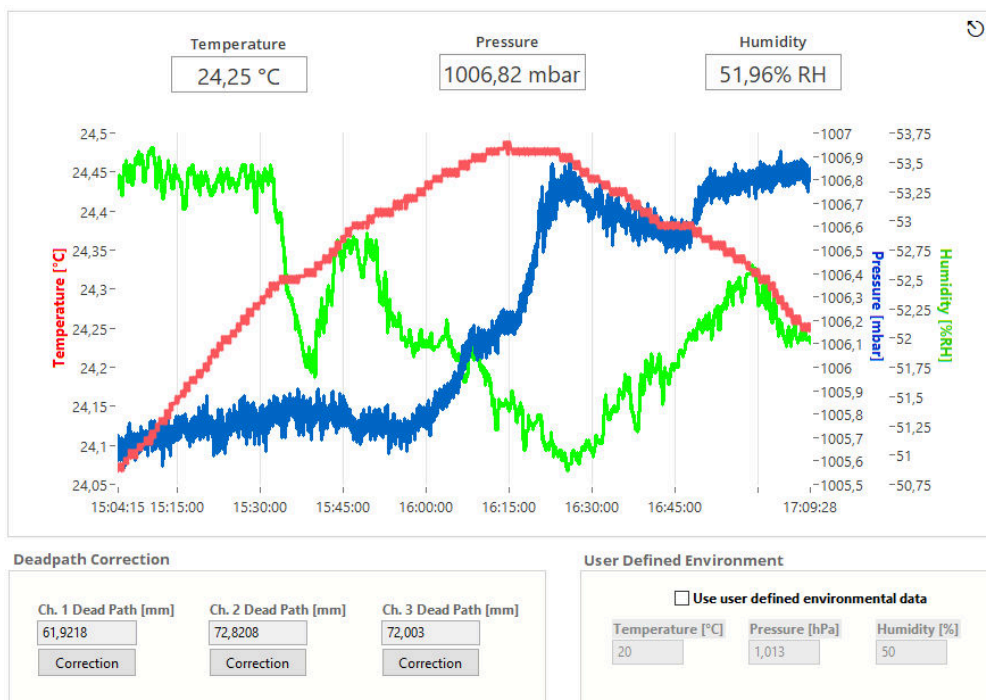
7.7 Environmental Monitor

Figure 7.24: Environmental Monitor.

The *Environmental Monitor* displays the temperature, humidity and pressure. When an environmental module is connected to the **PICO**SCALE and the GUI subscribes to the corresponding event, temperature, humidity and pressure are recorded automatically. The influence on the measurement can be corrected using the *Deadpath Correction* for the individual channels.

In the center of the display you find the environmental values plotted over time. Above the plot the current values are shown. The environmental module records data with approximately one Hertz sampling frequency and each plot can hold 24 hours of measurement data.

On the lower left hand side, the *Dead Path Correction* can be activated. During adjustment the **PICO**SCALE roughly determines the absolute distance between target mirror and sensor head and automatically determines the current dead path. The *Channel Dead Path [mm]* panels show the dead paths (in millimeters) of the active channels.

Only when the dead path correction is enabled, variations of the refractive index are taken into account and used for correction of position data. The dead paths can also be updated manually when you enter a new value and enable the dead path correction for the specified channel.

When user defined environmental parameters are inserted on the lower right side of the window a new adjustment described in chapter 7.2 will be necessary if you want to switch back to standard dead path correction. For further details on dead path correction, please refer to section 3.4.
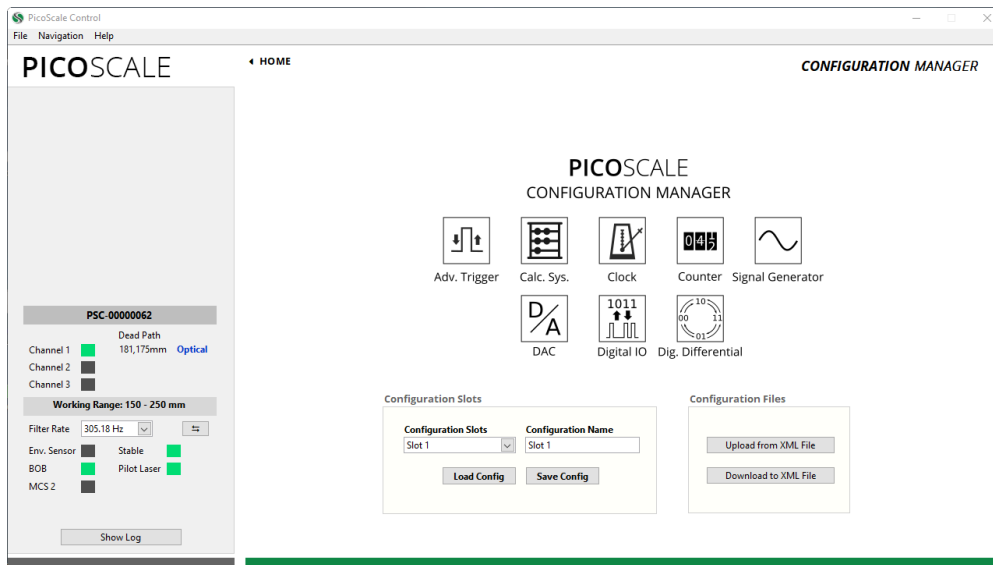
7.8 Configuration Manager

Figure 7.25: Configuration Manager. The current settings can be stored in so-called configuration slots. Each configuration slot can also be down- and uploaded to *.XML files.

The **PICO**SCALE allows to store specific configuration settings to provide an easy and efficient way to proceed your measurements after a restart of the system. Therefore, there are eight configuration slots available, that can be named freely. Each configuration slot contains the settings of the following modules:

- Advanced Trigger

- Calculation System, including look-up tables

- Clock Generator (*)

- Counter (*)

- Signal Generator, including custom shapes (*)

- Digital-to-analog converters

- Digital IO interface

- Digital Differential interface

(*) The outputs of these modules are disabled when the corresponding settings are loaded and need to be enabled when needed. This prevents unintended signal output.

Once you have configured your system, you may store the settings in a configuration slot which can optionally be renamed. The configuration slots are stored in the **PICO**SCALE internally. Additionally, you may download the active configuration (independently of the actual slots) to an *.XML file. This file can be uploaded and several **PICO**SCALE controllers can thus be configured the same way.
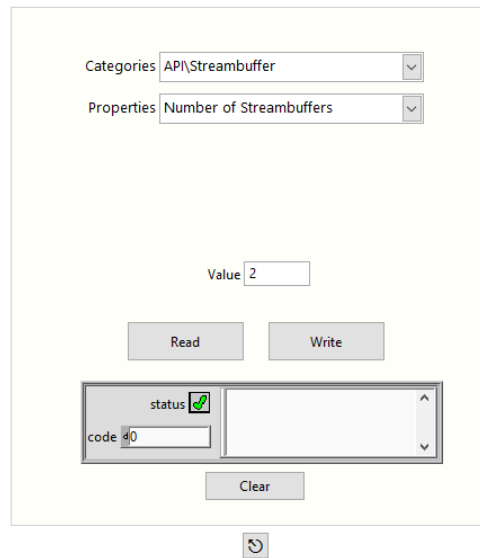
7.9 Property Dialog

Figure 7.26: Properties dialog box.

Properties are configuration values that define the behaviour of the device. The dialog can be reached over the menu *Navigation*, *Settings* and *Properties*. Each property has a data type and an access mode. Some properties may be read and written, while others are read only or (in rare cases) write only. Within the *Property Dialog*, you can read or write these properties. For a detailed description of the properties, please refer to the **PICO**SCALE *Programmer's Guide*. Please note that changing properties without due consideration may have significant consequences in the performance of the **PICO**SCALE.

8 *CONCLUDING REMARKS*

In this manual the basic operation principles, hardware and software of a **PICO**SCALE system are introduced. You should now be able to work efficiently with the **PICO**SCALE to perform position measurements with high accuracy. However, the **PICO**SCALE functionality goes far beyond measuring positions only. You may use it as a signal generator, timing module in your laboratory, data acquisition, perform basic calculations with high speed and many others. A selection of possible applications as well as summaries of key performances you can find in the application notes on SmarAct's homepage or on request. SmarAct will constantly add more and more application notes so it is worth checking the homepage regularly. You will also find an overview of convenient accessories there. However, if you do not find solutions for your application directly there, please do not hesitate to contact us. We will be very happy to help and try to find a solution for your precise measurement or implementation issue as quickly as possible.

We are convinced that the great versatility of the **PICO**SCALE offers great potential for many high precision metrology environments. Enjoy your **PICO**SCALE!

Sales partner / Contacts

Headquarters

SmarAct GmbH

Schuette-Lanz-Strasse 9
26135 Oldenburg
Germany

T: +49 441 – 800 87 90
Email: info-de@smaract.com
www.smaract.com

France

SmarAct GmbH

Schuette-Lanz-Strasse 9
26135 Oldenburg
Germany

T: +49 441 – 80 08 79 956
Email: info-fr@smaract.com
www.smaract.com

Israel

Trico Israel Ltd.

P.O.Box 6172
46150 Herzeliya
Israel

T: +972 9 – 950 60 74
Email: info-il@smaract.com
www.trico.co.il

Japan

Physix Technology Inc.

Ichikawa-Business-Plaza
4-2-5 Minami-yawata,
Ichikawa-shi
272-0023 Chiba
Japan
T/F: +81 47 – 370 86 00
Email: info-jp@smaract.com
www.physix-tech.com

South Korea

SEUM Tronics

801, 1, Gasan digital 1-ro
Geumcheon-gu
Seoul, 08594,
Korea

T: +82 2 868 – 10 02
Email: info-kr@smaract.com
www.seumtronics.com

USA

SmarAct Inc.

2140 Shattuck Ave. Suite 1103
Berkeley, CA 94704
United States of America

T: +1 415 – 766 9006
Email: info-us@smaract.com
www.smaract.com