iScanManual

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1 Product description

1.1 General

iScan The *iScan* is a tool to stabilize the optical frequency of tunable lasers to arbitrary set points (target values): An electronic feedback to the laser ensures that the actual optical frequency approaches the set point as closely as possible. Therefore, altering the set point will induce a controlled change of the laser frequency. The set point can be altered manually or programmatically, continuously or stepwise, immediately or upon external trigger. In this way, a variety of controlled laser frequency jumps and scans can be performed (see figure 1).

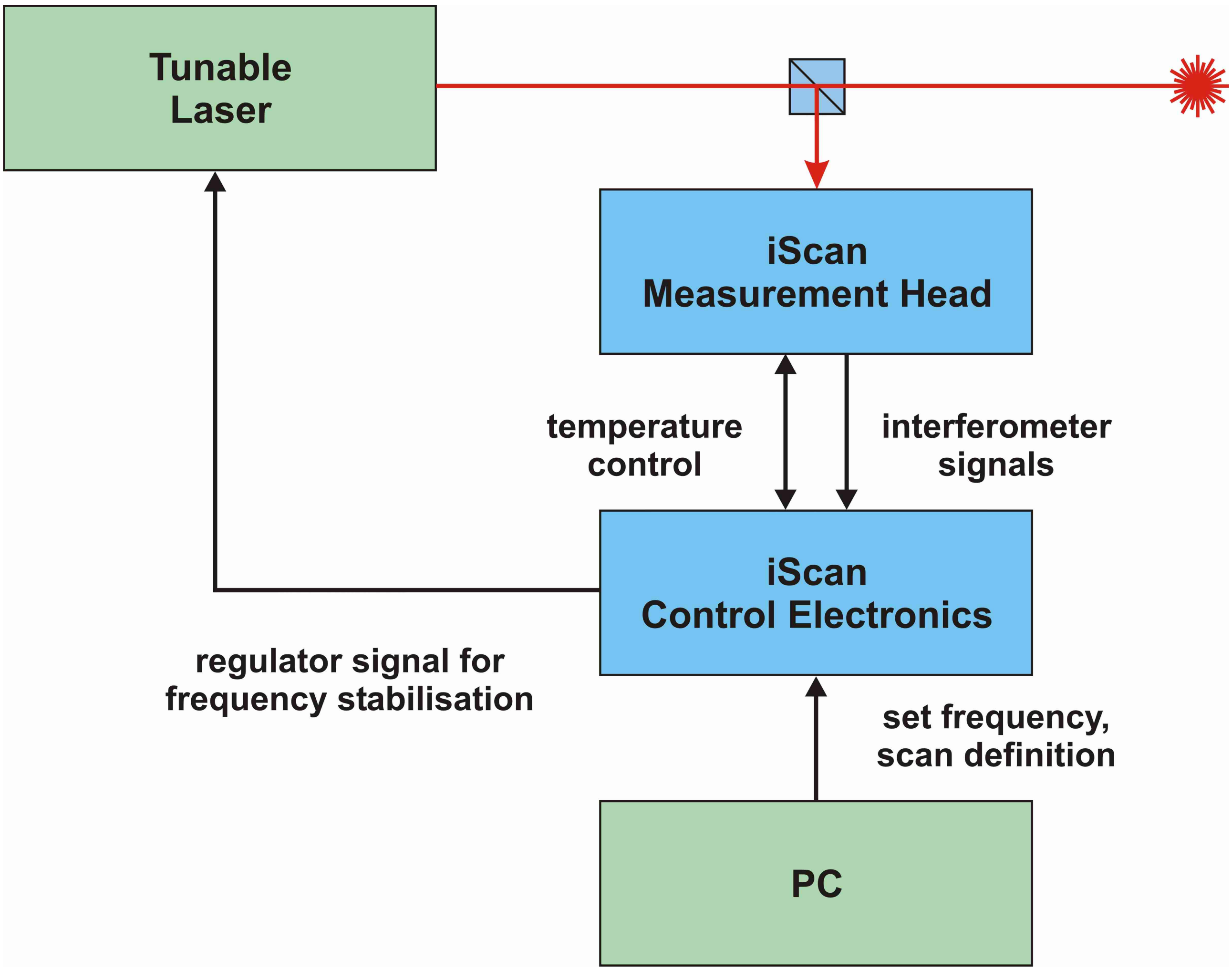


Figure 1: PhaseLock principle of operation

1.2 Functional components

iScan consists of an interferometric measurement unit ("iScan head") and digital control unit ("iScan DCU").
The sensor head converts the spectral properties of the laser light into electric signals, which in turn are evaluated by the DCU. Further sensors can anhance the system. For example, the spectoscopy unit *CoSy* provides an absolute reference to the frequency scale.

The DCU comprises two PID controllers as well as a scan function generator and a trigger section that provides the means for a fast and flexible control of the set point (target frequency).
Laser diode drivers and temperature controllers as well as high voltage amplifiers for PZT actuators and micro stepping motor drivers are available as add-ons.

iScan well applies for:

- Fast and precise scanning of tunable lasers
- Stepping to different arbitrary wavelengths
- Surveillance of the scan behavior of tunable lasers
- Measurement of the wavelength stability of tunable lasers
- Suppression of mode hops or mode instabilities
- Scan-synchroneous data acquisition

The *iScan* block diagram is shown in Figure 2 , which gives a first overview on the function blocks, the relation of the function blocks to each other, the switching options, as well as the inputs and outputs of *iScan*.

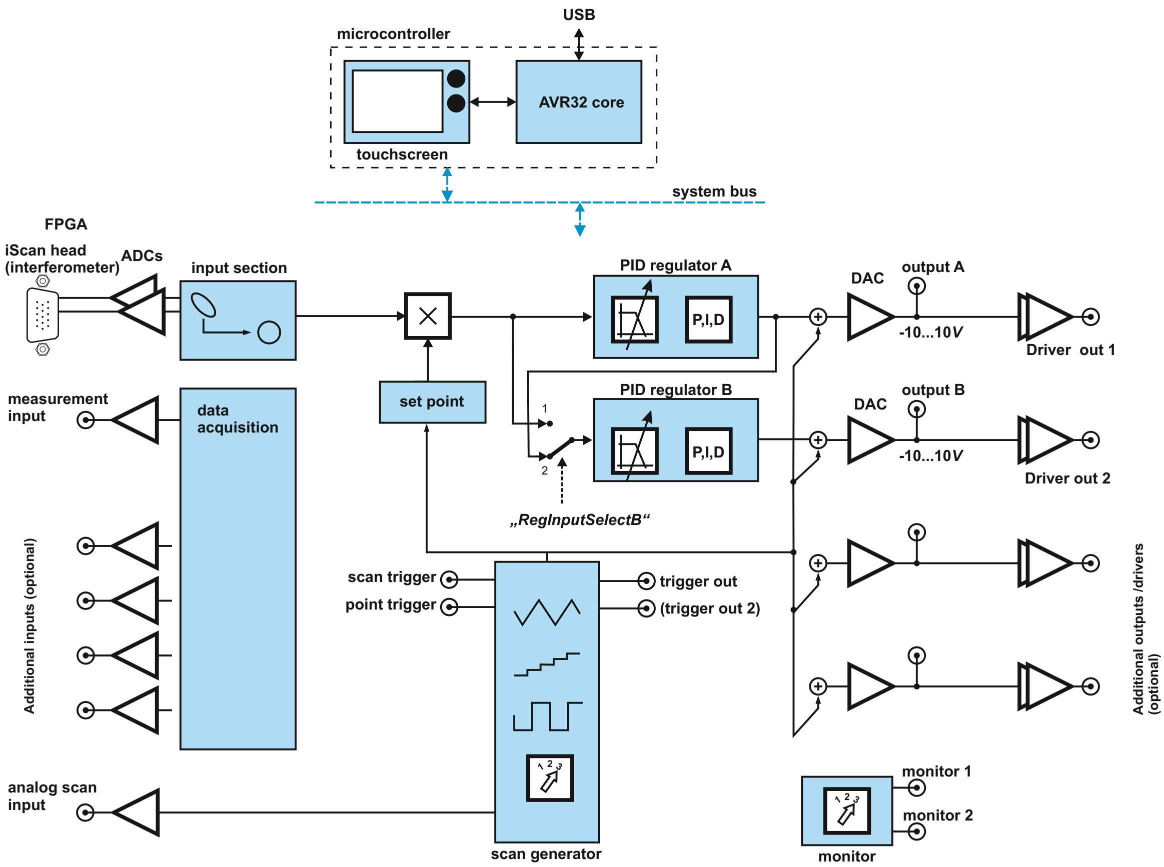


Figure 2: Schematic block diagram of *iScan* digital device

iScan combines all these components in a user-friendly compact device:

- iScan measurement head

- input section for signal conditioning
- phase–to–wavelength converter
- independent PID regulators, adapted especially to resonant systems like piezo-driven optical components
- output amplifier, user-selectable as high-voltage amplifier for piezo actuators, or as low-voltage amplifier generating a control signal for external amplifier sections
- scan section for the automatic generation of setpoints (target values)
- trigger section that organizes the exact timing of the scan steps

1.2.1 iScan DCU

The *iScan* Digital Control Unit (that comes either in a 19"-rack or in a desktop case) contains the heart of the iScan system. It receives analog signals from the sensor head, and provides analog output to operate a laser. It can be operated either manu-ally through a built-in touch pad TFT display, or by a PC through USB (optional: other interface lines). The control unit comprises several distinctive sub units: A microcontroller, an FPGA, an analog pre-processing board, a user interface, a power supply, and optionally drivers (see below). The iScan control unit will work with any tunable laser (e.g. diode laser, Ti:Sapphire laser or a dye laser). The actuator itself may be a piezo ceramic, a galvo scanner, a voice coil, a stepper motor or similar. For driving different types of actuators, the iS-can control unit is equipped with driver modules according to the demands of the laser, e.g.:

- Laser diode current driver
- Laser diode temperature controller
- Galvanometer driver
- Stepper motor driver
- High voltage amplifier for PZT or EOM

During normal operation, the iScan control unit generates a linear or arbitrary scan signal, which is used to control an actuator of the laser. The scan can be triggered by the PC or by externally applied signals.

1.2.2 iScan sensor head

The iScan sensor head (iScan head) uses a patented interferometric measurement setup (U.S. patent no. 6,178,002, German patent no. DE 197 43 493 A1) to produce two interferometric signals. These are sinusoidal functions of the optical laser fre-quency. Due to their 90 relative phase shift, the signals are called quadrature sig-nals (see fig. 3).

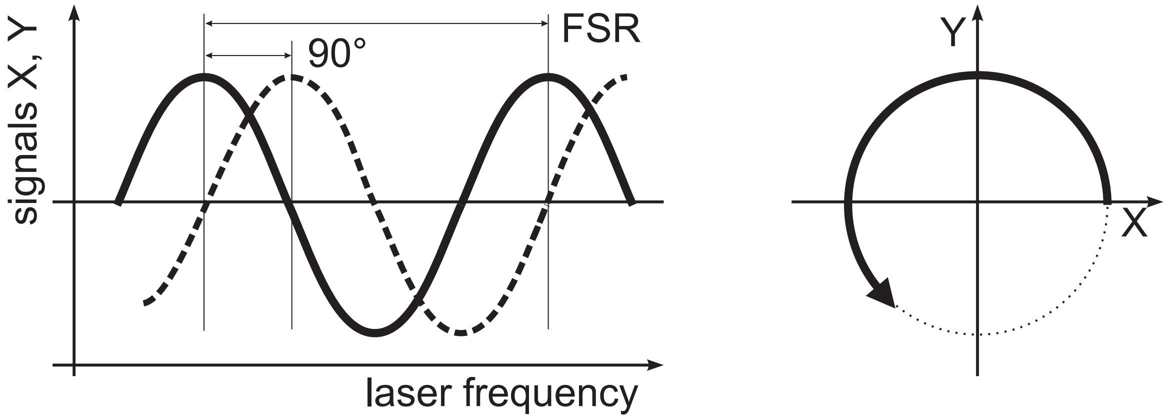


Figure 3: Quadrature signal pair derived from the interferometer

If displayed in x/y-mode on an oszilloscope screen, the spot will take a circular path if the frequency changes. Speaking in polar coordinates, the momentary angle of the X,Y-position represents the laser frequency, while the (electronically normalized) radius is a measure for the coherence properties of the laser (compare fig. 4).

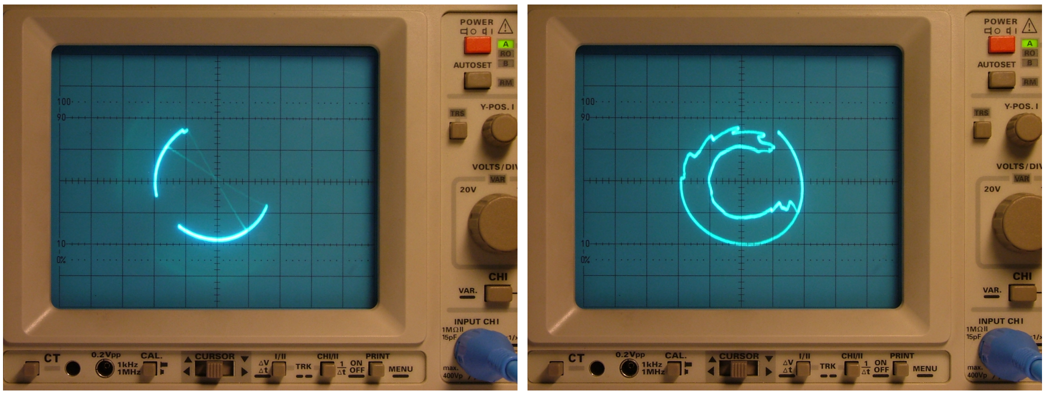


Figure 4: iScan quadrature signals showing a mode-hop (left) or a multi-mode state (right) of a scanning external cavity diode laser

The shape of the path allows easy diagnosis of the lasers 'health' (examples shown in Fig. section 6.8) In case of a longitudinal single-mode operation of the laser the radius is nearly con-stant. A full turn around the circle corresponds to a detuning of the laser by one Free Spectral Range (FSR) of the iScan interferometer. The FSR of the standard version of the iScan head is approx. 8 GHz. Other FSRs are available on demand.
The choice of the sensor unit can also be tuned to meet the demands of the actual application. For example special photo diodes allow to use the iScan sensor head in the mid-IR wavelength range .

1.2.3 CoSy: a compact saturation spectrocospy module

The spectroscopy module CoSy by TEM-Messtechnik will provide absolute stability. By combining such an absolute reference with the iScan interferometer head, your laser can be turned into an arbitrarily programmable optical frequency synthesizer. Also a wavemeter will provide absolute stability.

1.2.4 Fabry-Prot interferometer

A Fabry-Perot interferometer is available and may be chosen for better resolution.

1.3 Application

The iScan device acts as an intelligent scan generator. The microcontroller in the iScan control electronics is capable of calculating standard scans by itself, e.g. linear triangle or ramp scans, sinusoidal, rectangular or multipoint stepping scans, each with definable scan width, scan offset and scan speed. During the scan, the laser frequency remains locked to the iScan interferometer head by means of fast digital servo loops implemented in the FPGA. The servo parameters are under control of the microcontroller. A digital scan generator creates periodic or single-shot signal shapes, representing the time behavior of the laser frequency of the tunable laser. This scan can run in a continuous way, or it can be triggered in many kinds by external hardware signals or software commands. The scan shape can be created by the iScan controller on its own, or it can be created by an external PC and be transmitted via interface (USB, RS232, or Ethernet) to the iScan controller. The calculated set frequency will be transformed to signals, suitable for controlling the tuning elements of the tunable laser. (The number of tuning elements may be small, like simply controlling the grating position of an External Cavity Diode Laser (ECDL) by means of a piezo actuator. Or there may be a lot of tuning elements, like usual in a single-mode Ti:Sapphire ring laser. In addition, the iScan can control the measurement and hardware stabilization devices, used for bandwidth narrowing and measuring the exact laser frequency, with the task of correcting the laser frequency in a closed servo loop. It can read several analog and digital input signals for supervision of single mode behavior and frequency control.

2 Safety Instructions

Before operating the *iScan*, please read this user guide carefully in order to avoid any damage of the device or connected equipment as well as any injury to persons.

CAUTION! The *iScan* device is intended for laboratory use only. The *iScan* device should be operated by trained personnel.

CAUTION! The *iScan* device is used with lasers emitting visible or invisible radiation. Do not stare into the laser beam! Take precautions to avoid exposure of direct or reflected laser radiation.

CAUTION! The user is responsible for keeping the legal rules concerning laser safety that apply in their country. In Germany, this is the "Unfallverhtungsvorschrift BGV B2" of the "Berufsgenossenschaft der Feinmechanik und Elektrotechnik".

CAUTION! Use only the supplied power adapter and plugs or the corresponding ones for your country, as only this guarantees safe operation and grounding of the device.

CAUTION! The *iScan* is intended for indoor operation with a temperature range of $+10°C$ to $+40°C$. Do not subject to heat, direct sunlight or the influence of other electric devices. Protect from humidity, dust, aggressive liquids and vapors.

CAUTION! The *iScan* should be opened by trained technical personnel only. Before opening the housing, the device must be disconnected from the supply voltage, for example by pulling the power plug.
Please keep this manual within easy reach to refer to if needed. Give your *iScan* to third parties only with this manual.

3 Scope of delivery

Please check first of all if you obtained all the parts listed below. If not, please check your ordering form and refer to the manufacturer or distributor.

We recommend to keep the packaging material for future storage and transportation.

3.1 Mandatory components

- *iScan* DCU electronics in desktop or 19" rack case
- *iScan* sensor head
- 15-pole cable with high density Sub-D connectors (male – female)
- Country specific power cord
- USB A – B cable
- USB memory stick containing PC software
- This manual

3.2 Optional parts

Upon explicit order, the following components are integral parts of the *iScan* electronics

- High voltage amplifier for PZT actuators
- Driver for a stepping motor
- Diode laser driver (current and temperature control)
- Galvo drivers

Similarly, the following components may be an integral parts of the *iScan* sensor head

- *FiberEtalon*, a fiber-based marker etalon for the linearization of the frequency scale
- *CoSy*, a compact spectroscopy unit
- A full DFB laser diode package may be integrated into the sensor head so that it mutates into a laser.

3.3 Alternative parts

The low voltage supplied version of *iScan* comes with an external AC-to-DC converter power supply (mains adapter) 12W DC, min. 30W.

4 Brief description of the control elements

4.1 Front panel elements

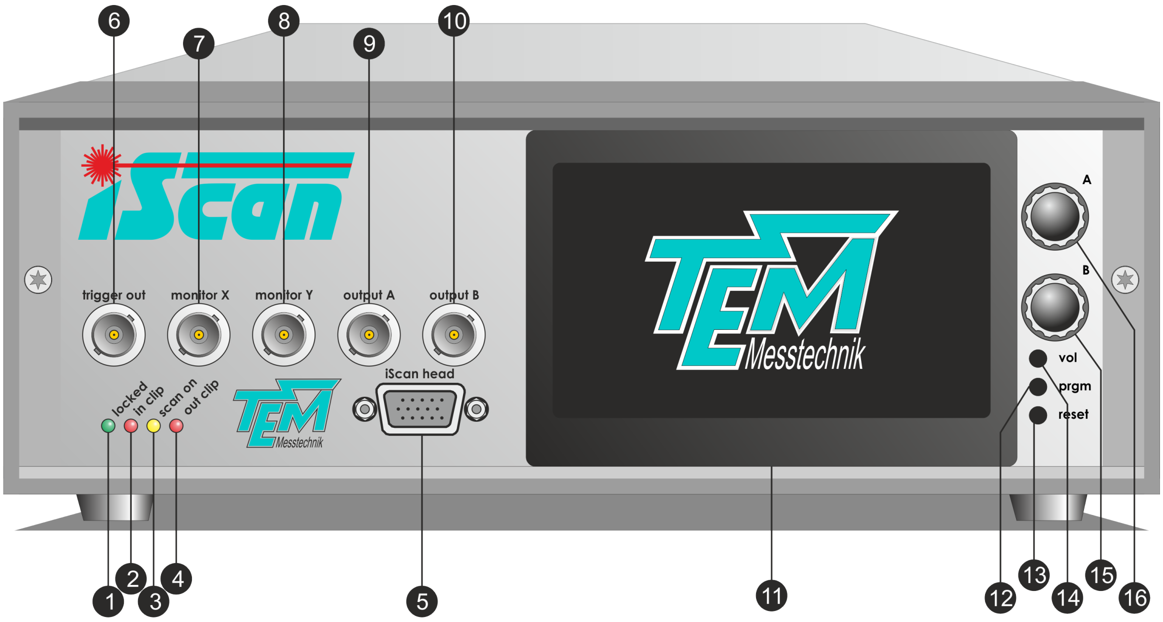


Figure 5: Front panel elements

Nr.	Description
1	LED locked. Turns on whenever the error signal of all enabled regulators is within a small range
2	LED input clip. Indicates too a large input signal (too much optical power in the iScan head), or normalization overflow
3	LED scan on. Turns on when laser is being scanned
4	LED reg clip. Turns on when any of the regulators reaches the limit of its output range
5	"iScan head" HD15 Socket. Feedback measurement input for sensor quadrature signals
6	trigger out BNC plug. Provides a TTL signal that indicates the start of a scan / a scan step / locked condition of regulator
7	"monitor 1" BNC plug. Can be used for observation of internal signals
8	"monitor 2" BNC plug. Can be used for observation of internal signals
9	"output A" BNC plug. Regulator output signal (low voltage: -10V...+10V). For HV amp output see rear side
10	"output B" BNC plug. Regulator output signal (low voltage: -10V...+10V). For HV amp output see rear side.
11	4.3" TFT touch screen
12	Programmer button. Only used for flashing firmware to the microcontroller.
13	Reset button. Resets the microcontroller.
14	Loudspeaker volume potentiometer
15	Rotary knob B. To change the digital place when editing a numerical value, turn the wheel while keeping it pressed.
16	Rotary knob A. To change the digital place when editing a numerical value, turn the wheel while keeping it pressed.

Optional connectors:

- Scan and point trigger input: These TTL inputs allow for the synchronization of the frequency scan with other devices. Their functionality is programmable. The scan trigger can start/stop a scan, while the point trigger triggers a frequency step within a scan.
- Analog scan input: Analog input that allows a proportional shift of the frequency setpoint
- CoSy A, B: Analog inputs for spectroscopy signals (giving the frequency scale an absolute reference)

4.2 Rear panel elements

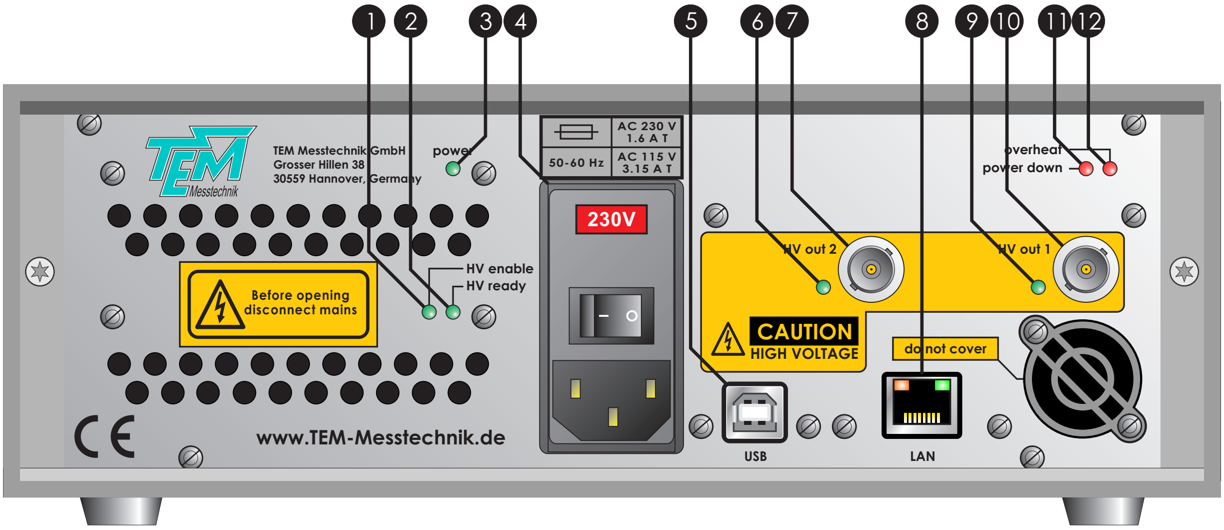


Figure 6: Rear panel elements (standard and HV version)

Nr.	Description
1	(only with HV option) “HV enable” green LED: The voltage from the HV supply has been applied to the amplifier stage
2	(only with HV option) “HV ready” green LED: HV supply module is powered on
3	“power” green LED: Power-on indicator
4	AC power socket with primary switch and fuse holder
5	USB connector
6, 9	(only with HV option) bicolor LED: output voltage indicator for HV out 2, 1 (green: actual output voltage low, red: actual output voltage high)
7, 10	(only with HV option) high voltage output channel 2, 1 BNC jack (corresponding to output B and A signal, resp.)
8	(optional) Ethernet LAN connector (RJ-45)
11	“power down” red LED: This LED is lit when the amplifier voltage is disabled due to overheating or overcurrent
12	“overheat” red LED: Lit, if the HV amp stage is overheated and the output voltage is switched off.

4.3 Touch screen

4.3.1 Navigate through the menus

After start-up or reset of the μC, press "menu" to enter the main menu. In list-like sub-menus, you can scroll through the list using the rotary knob or by hitting the displayed up/down keys.

4.3.2 Changing parameters

In order to change a displayed parameter, hit the corresponding number on the TFT. The number will then by highlighted, and an underscore will indicate the digit being edited. Use the wheel "B" to adjust the number to the desired value. Turning the wheel while keeping it pressed will change the digital place being edited. Hit the number again to stop the editing. NOTICE! Changed values apply immediately, i.e. without further confirmation.

4.3.3 Display settings

To adjust display settings like LED backlight brightness or screensaver settings go to (*menu* → *miscellaneous* → *display settings*)

Backlight brightness
The brightness of the LED backlight can be adjusted in 10 steps e.g. to avoid bright display illumination in dark rooms.

Screensaver
When displaying a static image for long periods of time the LCD displays can create a permanent ghost-like image. A static picture burns into the display and the image quality degrades. To prevent this burn-in effect the display becomes white after an adjustable delay time. You can return to the menu by touching the display.

Beeper volume Use a screwdriver (size 2.5 mm) to tune the beeper volume.

Reset button Pressing this button will restart the micro controller with the last saved parameter set. To reset all parameters to factory default, enter navigate to *menu* → *miscellaneous* → *load/save* → *factory settings*. NOTE: All parameters can be accessed by the PC interface as well. Refer to section 9.1 for more information.

5 Installation

5.1 Placement

Place *iScan* DCU suitably, taking into account the safety warnings in chapter 2. The *iScan* sensor head should be placed in a location with constant ambient conditions, preferably on an optical table. In case of a Twin iScan system, place both iScan sensor heads close to each other, i.e. in the same environment.
If you have purchased an iScan sensor integrated into a laser (e.g. the TOPTICA DL100 system), place the laser head according to the manufacturers advice.

5.2 Mains Connection

iScan DCU has an IEC power socket at the rear side (unless otherwise ordered, see section 5.3). Use the delivered power cord for connection to the AC mains. If country-specific cables are required use high quality power cords, fitting to the local power supply outlets. *iScan* accepts AC power supply in a wide voltage range (100. . . 240 V AC, 50. . . 60 Hz). The primary mains switch and the fuse holder are located next to the IEC socket at the rear side (see section 4.2). For fuse rating, see label next to the holder.

5.3 Alternative DC power supply

Upon special order, *iScan* may be equipped with a DC supply socket instead of the AC power supply. In that case, use the AC-to-DC converter power supply ("mains adapter") delivered with the *iScan*. Alternatively, any other standard DC power supply with voltage from 12. . . 24 V and minimum 30 W power rating may be used. The connector must have 5.5mm outer and 2.5mm inner diameter, plus pole at the inner contact. Please note that no primary switch nor a fuse holder are present for the DC supply. The device will start up right after the connection has been made.

5.4 Connection to PC

Regularly, *iScan* can work completely as a stand-alone device. However for automatic calibration, a PC program is required, which provides tools for linearization (using the *FiberEtalon*) or absolute referencing (using the *CoSy*, e.g.).

Alternatively, you might find the "Kangoo" software helpful for the visualization and the adjustment of parameters. If you wish to connect *iScan* to a PC, use the delivered USB cable. For software and driver installation refer to section 8.

5.5 Optical adjustment

5.5.1 Fiber-coupled sensor head

If your iScan sensor head comes with a fiber connector, prepare a setup to couple approximately 0.1. . . 1 mW (unless otherwise noted) of the laser light into the fiber, such that the polarisation is oriented in line with the connector's key. The optimization of the fiber coupler can be done later on during the signal adjustment (section 6).

5.5.2 Free-beam sensor head

If no fiber connector is supplied, insert the iScan sensor head suitably into the free laser beam of your experiment according to fig. 7.

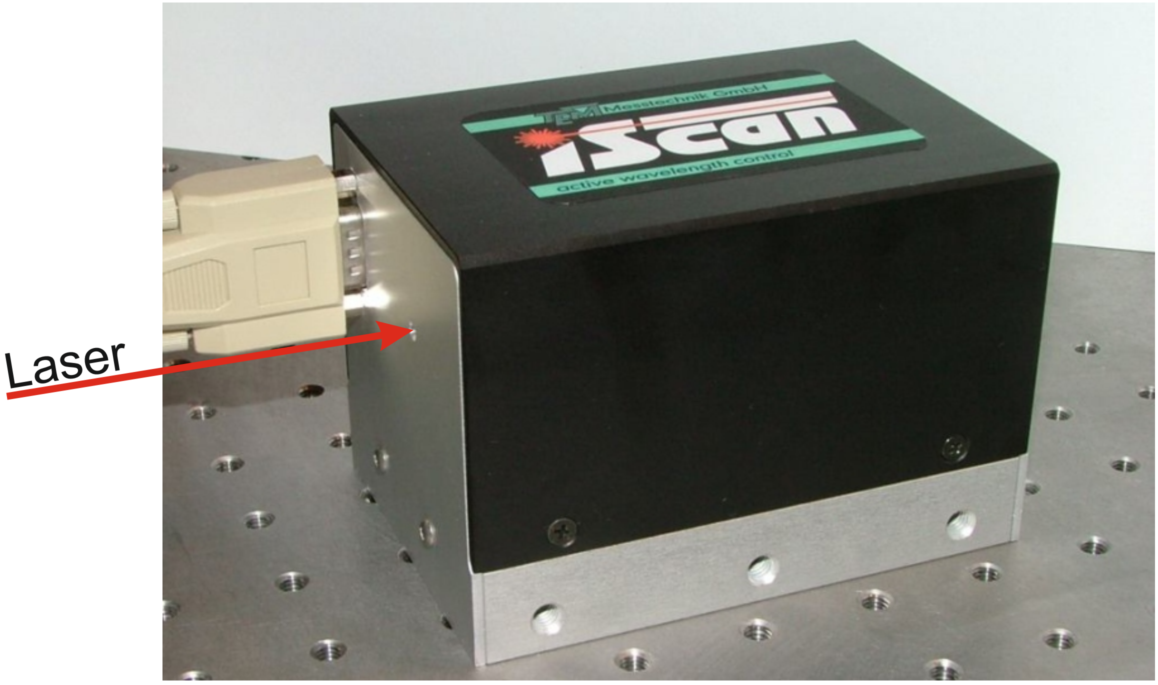


Figure 7: Laser entrance aperture of the iScan head when using a free beam

The beam must enter the aperture at normal incidence (see the description of the alignment below). For an optical power below 10 mW, the polarisation must be oriented perpendicular to the table surface. If the optical power exceeds 10mW, a polarization parallel to the table top is preferable.
Note: Any change of the polarization state during operation affects the stability of the frequency regulation!
Note: If you wish to use the transmitted beam in your experiment, make sure that no reflected or scattered light re-enters the iScan head, as this will disturb the interferom-eter signals and thus reduce the frequency stability of the regulation scheme.
In case of a Twin iScan system, make sure that the light of only one laser enters each *iScan* head.
For precise adjustment, we recommend to proceed as follows (see fig. 8):

- Fix a straight metal bar with rectangular cross-section to the table for a physical reference line.
- Put the iScan head flat on the table, the lower edge of one of the long sides coinciding with the reference line

Then iteratively repeat the following steps

- Move the iScan head along the reference line to position a.
- Adjust the beam position such that the beam hits the middle of the input hole
- Move the iScan head along the reference line to position b.

- Adjust the beam *angle* such that the beam hits the middle of the input hole also in this position.

In this way, the beam is parallel to the reference line and thus the long edges of the measurement head.

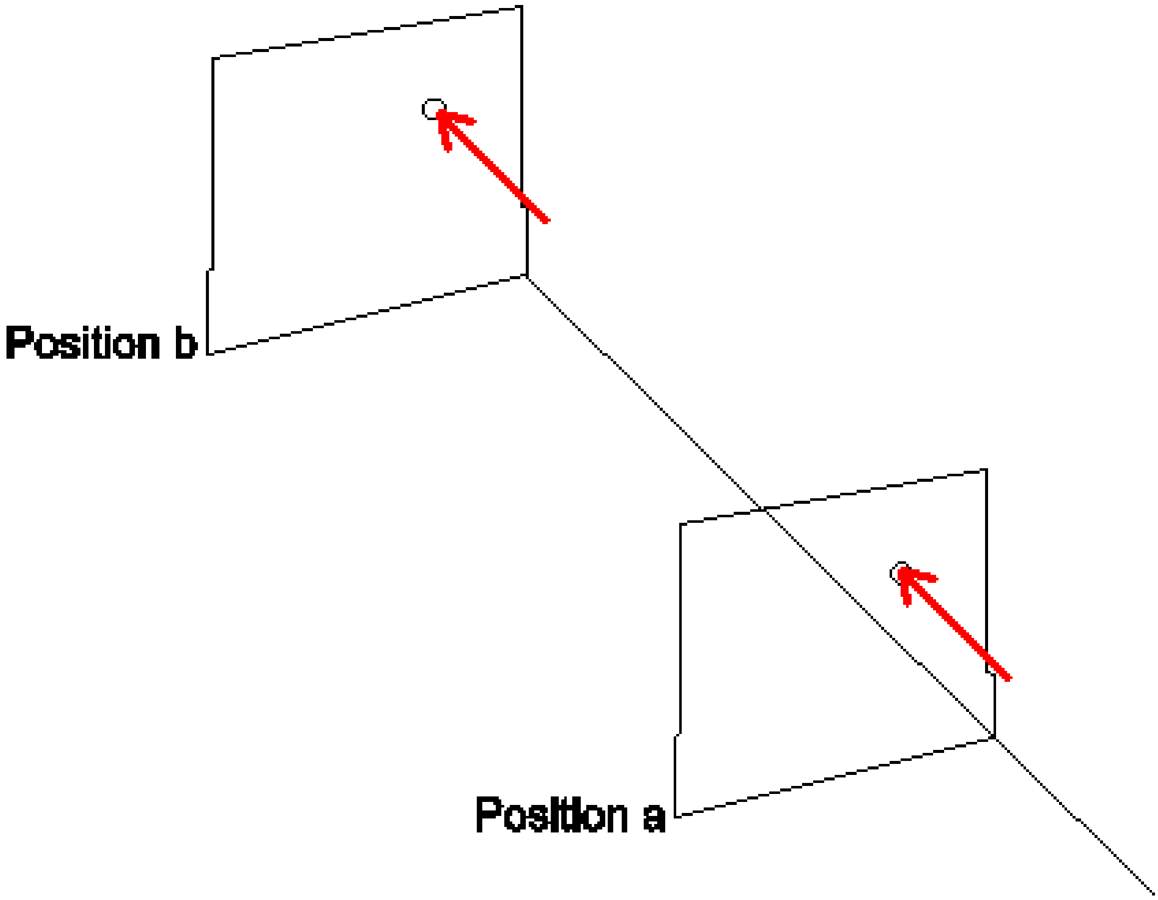


Figure 8: Optical adjustment of the *iScan* head when using a free beam

Now fix the measurement head to the table and remove the metal bar. If you have a version with output aperture, you can also check the correctness of the adjustment by measuring the optical power transmitted by the *iScan* head.

5.6 Connection of the iScan sensor head

Connect the *iScan* head to the “iScan head” connector of the *iScan* device (see figure **??**), using the HD15-cable delivered with your system. (In a Twin iScan system, connect each iScan head to the corresponding HD15 socket of the iScan control unit.)

NOTE: Use no other cable than the one delivered with your iScan system. Using standard cables like those used for personal computers can lead to malfunction or damage of electronic components!

Remark: Please note that the amplitude of the signals inside the sensor head is adjusted remotely by the *iScan* 's signal processor. Therefore, this connection must be made *before* power up.

5.7 Output signal connections

The signal processor inside the *iScan* DCU provide 3 signals to control the laser frequency: Two analog voltages (accessible via the output BNCs on the front panel) and a 2-phase stepper motor signal (provided by the appropriate driver, if present).

Turn off the iScan control unit to make sure that the device is powerless when you connect your laser to the outputs, according to one of the following subsections.

5.7.1 Direct use of the analog outputs

If a voltage ranging from -10. . . 10 V is sufficient to tune the laser, simply connect the laser's tuning input to the BNC labelled "output A" on the front panel. If two voltages are required, use "output B", too. If the actuators attached to A and B have different response speed, choose output A for faster one.

5.7.2 Using built-in drivers of the iScan DCU

When using the built-in drivers of the iScan system, connect the laser tuning components directly to the adjacent jacks at the rear side of the iScan control unit:
If a high voltage amplifier is installed, amplified copies of the output A and output B voltages are available at the "HV out 1" and "HV out 2" BNC connectors at the rear side.

NOTE: Before connecting PZTs, please check that they comply with the output voltage range of *iScan* (standard: 0. . . 150 V)!

If your laser is equipped with *one* PZT actuator to control the frequency, "HV out 1".

If your laser is equipped with *two* PZT actuators (one for fast and the other one for slow but large-range control), connect the fast PZT to "HV out 1" and the slow one to the "HV out 2".

If your laser is equipped with a motorized stage to coarsely adjust the frequency, connect it to the "Motor" connector at the rear side.

For the connection of a laser diode to the *iScan* DLD laser driver module, please refer to the corresponding DLD manual.

5.7.3 Connections to third-party laser drivers

Turn off the iScan control unit to make sure that the device is powerless when you connect your laser. If the laser comes with its own driver electronics, connect the iScan control units "output A" to the frequency modulation input of the laser driver. If the laser provides two frequency modulation inputs, connect "output A" to the fast and "output B" to the slow modulation input of the laser driver.

Example: Connection to a DFB laser diode via the TOPTICA DLCpro
The iScan scans and controls the optical frequency of the DFB laser diode by current and temperature and therefore needs access to the respective set points in the Toptica DLCpro. In order to prevent

excess current/temperature values to be applied to the laser diode, the following settings should be made before the *iScan* DCU is connected with the DLCpro:

1. On the DLC pro front panel, press the Scan/Lock Mode button or tap the corresponding symbol to access the Scan/Lock mode or the Wide Scan mode.
2. Press the Parameter button or tap the corresponding symbol to access the context parameter menu.
3. Select "Analog Remote Control → CC" in the context parameter menu to configure a CC output offset.
4. Enable control via external voltage [1: enabled]
5. Signal Input: Specify the BNC connector for the external voltage ["Fast In 3", 2]
6. Factor: Set the conversion factor for converting the external voltage [V] into a CC output offset [mA] to "1". This means that 1V of control voltage converts to 1mA change of the laser current.
7. Select "Analog Remote Control → TC" in the context parameter menu to configure a TC output offset.
8. Enable control via external voltage [1: enabled]
9. Signal Input: Specify the BNC connector for the external voltage ["Fine In 1", 0]
10. Factor: Set the conversion factor for converting the external voltage [V] into a TC output offset [K] to "1". This means that 1V of control voltage converts to 1K change of the laser temperature.

Then connect the *iScan* DCU to the DLCpro according to fig. 9:

1. Connect the "Output A" BNC of the iScan DCU to the "Fast 3" BNC of the DLCpro (5)
2. Connect the "Output B" BNC of the iScan DCU to the "Fine 1" BNC of the DLCpro (4)

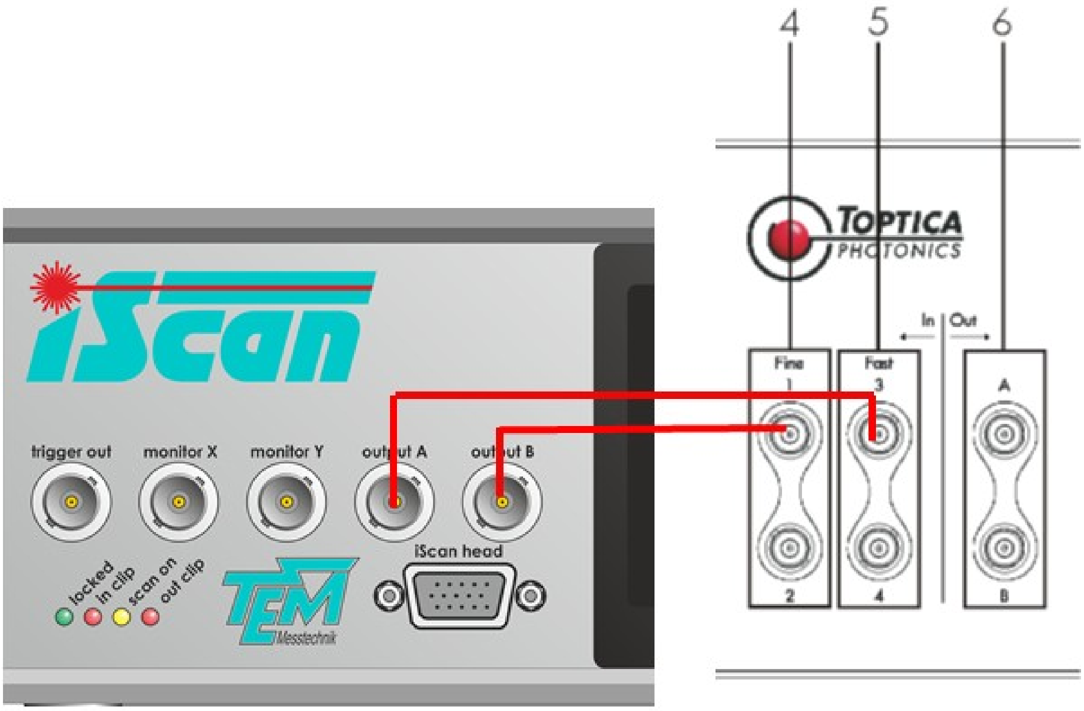


Figure 9: Connection of the *iScan* DCU to the Toptica DLCpro laser controller

Example: TOPTICA DL110 (PZT only)
If you use TOPTICAs DL110 diode laser, connect the iScan control unit's "output A" to the BNC jack of the "Analog Interface DCB110" module of the DL110 supply rack. Provided that the jumpers on the DCB110 are set accordingly, the signals applied to the DCB110 will be amplified by the "SC110 Scan Control" module and thus result in frequency detuning of the laser.

NOTE: When using TOPTICAs DL110 laser controller, other locking modules (such as DigiLock, PID, LIR) must be removed from the rack, as they use the same backplane connections for laser tuning!

Example: TOPTICA DL110 (PZT and laser current)
For fast regulation, connect the iScan control units "output A" to the "modulation in" BNC of the DCC110. This connection provides fast access to the laser current. Connect "output B" to the DCB110 as described above.

Example: Wavelength Electronics LDTC0520
If you use tunable DFB laser diodes with built-in TEC, supplied by a temperature and current controller LDTC0520 by Wavelength Electronics, connect the iScan control units "output A" to the "EXT LD SET" input and "output B" to the "EXT T SET" input. You need to use voltage dividers to adapt the output voltage range of the iScan DCU (–10. . . +10 V) to the input voltage range of the driver (0. . . 2 V and 0. . . 3.3 V, resp.).

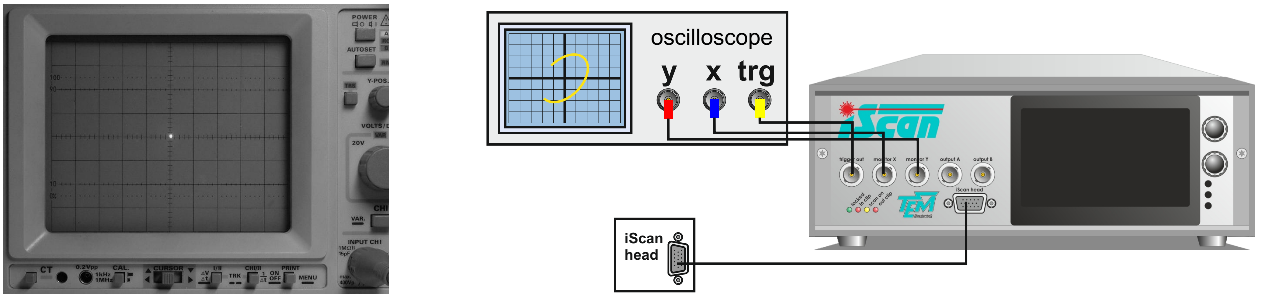


Figure 10: Oscilloscope screen after offset adjustment, *before* the iScan unit is switched on.

6 Getting started

6.1 Overview

The following sections describe how to take *iScan* into operation from the beginning, step by step. These chapters can be used for becoming acquainted with *iScan*, as well as for function testing of the device. It is strongly recommended to read through chapter 4 on page 13 first. Please follow chapter 5 to accomplish all necessary input and output connections of the *iScan* DCU.
In addition to that, several signals in the signal path must be checked for their shape and size during the installation process. For this end, a 2-channel oscilloscope capable of X-Y display mode with at least 5 MHz input bandwidth is required. An analog oscilloscope is a good choice. However if you use a digital one, make sure the sampling rate is at least 10 MHz to avoid aliasing effects. Connect the oscilloscope inputs to the BNC jacks "monitor x, y" on the front panel — see figure 10). Set the input sensitivity of the oscilloscope channels to 2 V/div and remove / switch off any 50 Ω matching resistor. Switch the oscilloscope to the X–Y display mode. While the DCU is still off, adjust both horizontal and vertical input offset so that the spot is exactly in the center of the screen as shown in figure 10).

Start with the *iScan* installed according to section 5 and switched *off*.

6.2 Using the PC visualization software "Kangoo"

Even though the *iScan* device can work completely as a stand–alone device, it is very helpful and strongly recommended to use "Kangoo" for the visualization and the adjustment of parameters. For automatic calibration, a further PC program is required, which provides additional tools for linearization (using the *FiberEtalon*) or absolute referencing (using the *CoSy*, e.g.) — see section refsubsec:CalibrationSoftware. If you wish to operate *iScan* by the frontpanel touch screen, just proceed with section **??**. All explanations will be given for software and front panel operation, as far as both are available.

6.3 Kangoo graphical user interface

If "Kangoo" has not yet been installed on your computer, please follow the instructions in chapter 8 on software and driver installation. If you start Kangoo for the first time, the "Welcome" GUI will show up. Navigate to the *iScan* configuration.

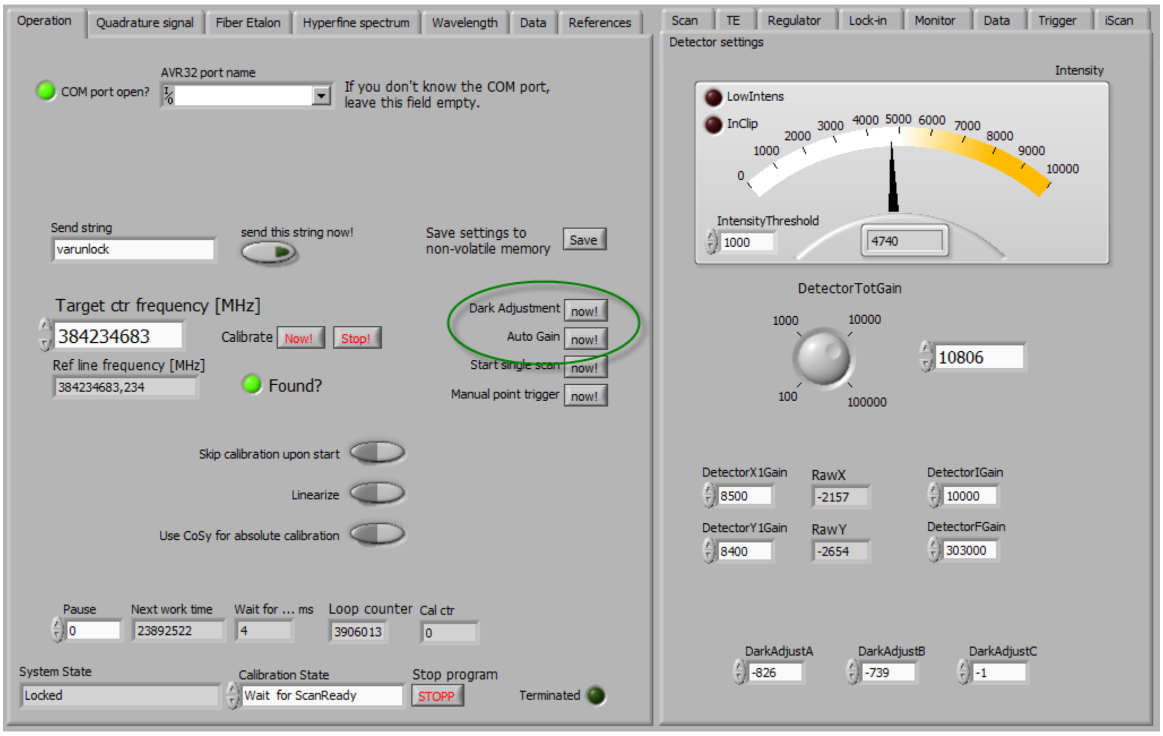


Figure 11: Calibration Software with buttons for dark adjustment and auto gain highlighted

6.4 Calibration software

The calibration software provides access to all parameters required during the “getting started” process, see fig . 11.

6.5 Switch the device on

If you operate the iScan system for the first time, block the laser beam or switch off the laser. (This step is not necessary on a daily basis.)
Turn on the main switch on the rear side. Given a few seconds for booting, the device will be ready for use after a short acoustical signal. The display will show the home screen as shown in fig. 12.

6.6 Establish PC communication

Connect the *iScan* to the PC by means of a standard USB (A-B) cable. (Please avoid cables longer than three meters, especially if strong electromagnetic fields are present in your environment). The device will appear as “TEM uC Virtual Com Port” in the device manager of your computer.
Start the Kangoo software and type F5 (or go to Communication → COM parameters) to open the interface dialog (compare fig. 13). Click to “check!” in the COM Parameters windows to search for available COM ports. The COM number of *iScan* should appear in the drop down list next to the button. The port settings like baud rate, data bits und parity settings are important for “real” COM ports e.g. RS-232. They will be ignored for USB connections.
To test the communication click ”show COM window” in the dialog. Click into the window named ”COM-Terminal” and press ‘ENTER‘. The device should answer with ”no command. . . ” (compare

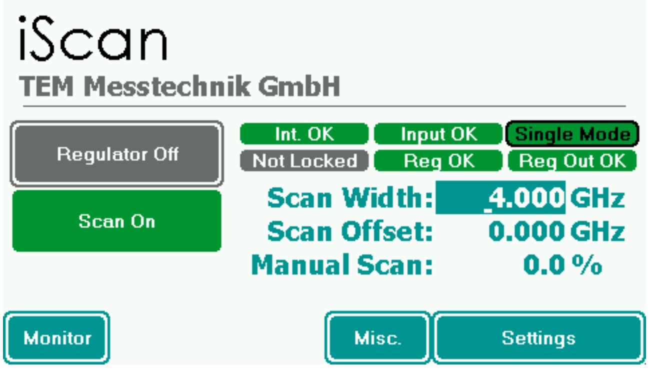


Figure 12: Home screen on the TFT display after power–up

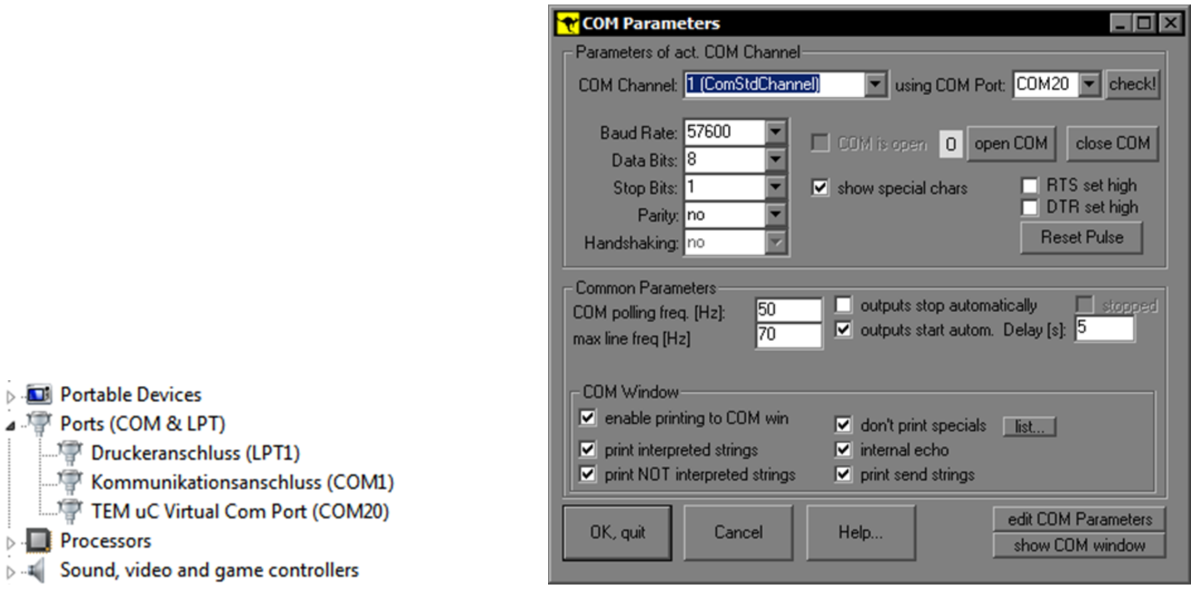


Figure 13: COM Port in the device manager (left) and corresponding COM port settings in Kangoo (right)

fig. 14).

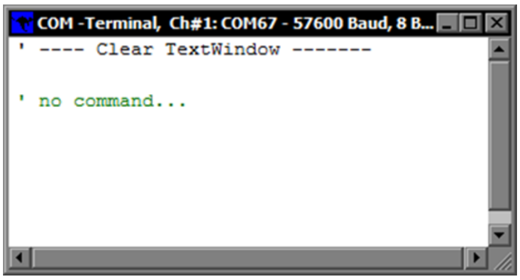


Figure 14: COM Terminal window

Later on, you may use this terminal window to learn how to control your device by simple ASCII commands. Just try and enter "hello" followed by the 'ENTER' key ...

Then return to the *iScan* configuration (GUI) and press the key "u" or click *Objects* → *all device*

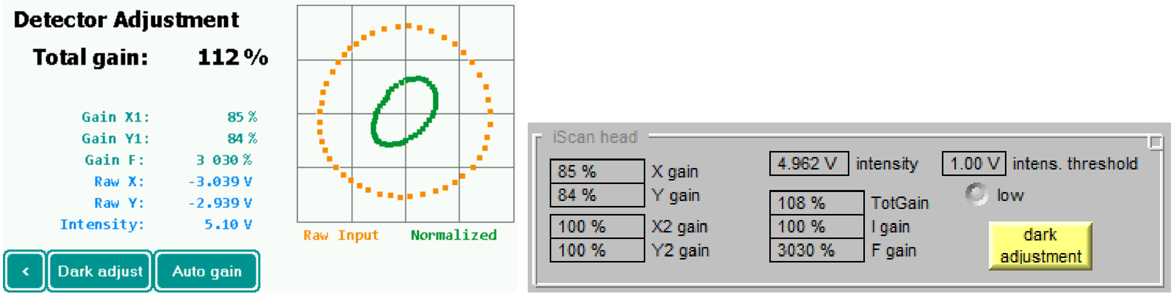


Figure 15: Detector adjustment menu on the TFT and in the Kangoo GUI

values update (u) to retrieve all actual settings from the *iScan* device to the PC.

6.7 Sensor settings

The *iScan* sensor head contains amplifiers with remote gain control. First of all, these gains have to be adjusted so that the signals reach a useful level. For this end, when operating the *iScan* by PC control (Kangoo software), localize the "Detector settings" elements in the GUI(fig. 15, right) or in the calibration software (fig. 11). When operating the *iScan* by the touch panel, press the button "Settings" (for Twin iScan: head1 or head2, resp..). Then choose "Input adjustment", then "Detector settings". The screen will show up like in fig. 15, left hand side — however the displayed x–y traces will be different in most cases.

6.7.1 Dark offset adjustment

The optical signal level in the sensor head is displayed as "Intensity". The values of "Raw x" and "Raw y" represent the actual values of the quadrature signal. As long as no light enters the sensor head (because the laser is off or the beam ist blocked), the signal levels should be close to zero. You can adjust them to exact zero by clicking "dark adjustement" in the Kangoo GUI or by hitting the "Dark adjust" button on the TFT. The calibration software also has a "Dark adjustment" button, see fig. 11.

6.7.2 Overall gain adjustment

Switch the laser on or open the beam path so that the laser light enters the sensor head. Adjust the parameter "Total Gain" so that the intensity is in the range of 4...6 V.
Remark: To change the parameter, touch the respective number on the display so that it is marked up. Then turn the knob B to edit the underlined digit.
Remark: In order to select the digit for editing, turn the knob while keeping it pressed.

You may iteratively optimize the fiber coupler to increase the actual optical power level in the sensor head. After each optimization step, press "Auto gain" to trim the "Total gain" value.
Next watch the values "Raw x" and "Raw y". They should lie in a range between -5V and +5V. If this is not the case, increase or decrease the respective value "Gain X1" or "Gain Y1" until this range is reached. The exact value is not important for now.

6.8 Input Signal Monitor

For the next steps, the x–y signal pair should be displayed on the oscilloscope (see 7.1 for details). For this end, choose the raw signals as output to the monitor BNC connectors: When operating the *iScan* by the touch panel, press the button "Monitor". This opens up a list of options through which you can scroll either by the up and down buttons on the right hand side or by turning the rotary knob B. Select "Raw input only" by hitting the corresponding button. Leave this menu by pressing "<" once and return to the "Detector settings" menu.
When operating the *iScan* by PC control (Kangoo or calibration software), click to the selector "monitor 1" and choose "raw X", then click to the selector "monitor 2" and choose "raw Y".

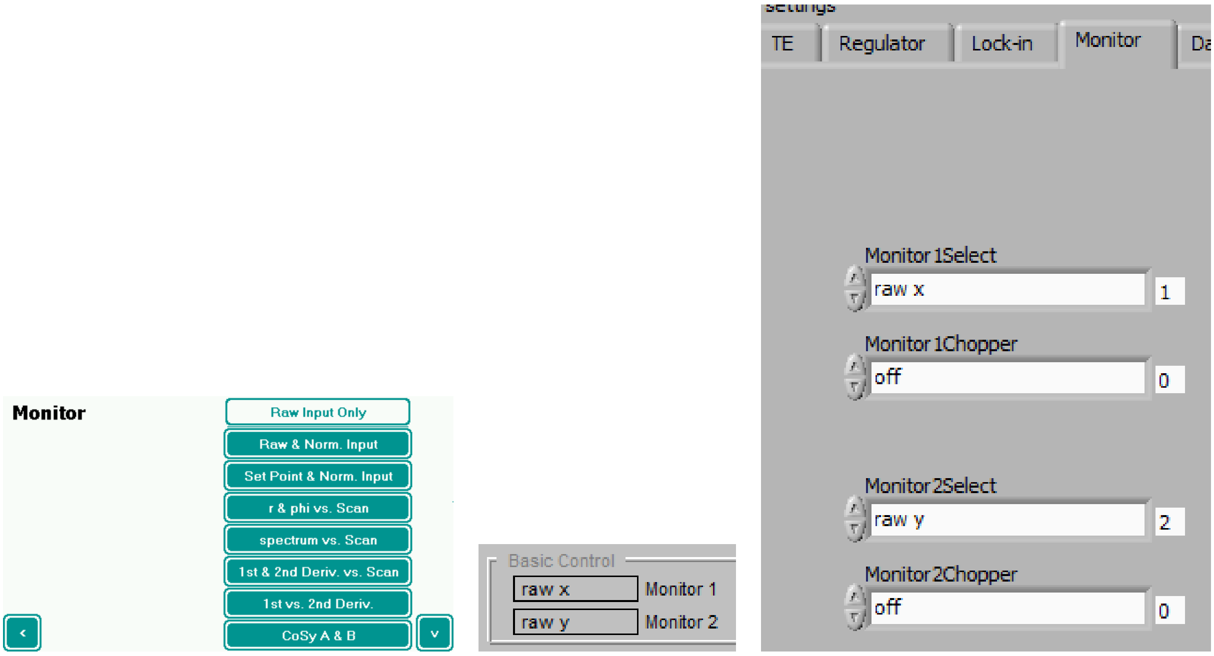


Figure 16: Monitor menu (left) and the corresponding GUI elements (middle and right)

The oscilloscope now displays the sensor output signals (quadrature signal pair) as it is received and digitized by the *iScan* DCU. As long as the laser frequency is constant (not scanned), the signals x and y are constant. In x-y display mode, they appear as a dot on the screen. The voltages should be roughly the same as the values for x and y in the "Detector settings" menu.
Now the quadrature signals have to be trimmed to reach an amplitude of about 12 V peak-to-peak. For this end, a frequency scan has to be set up, so that the dot in the X–Y plane expands to a circle.

6.9 Tuning elements and blind–flight scans

The *iScan* is a combined frequency locker and scan generator: The laser frequency is locked to an arbitrary setpoint, and changing the latter while make the laser change the former. However, the work of the feedback mechanism is eased when the scan signals are also directly applied to the tuning elements, thus bypassing the servo loop — that is in a "feed-forward" manner (see fig. 17). There are three parameters that determine the effect of the scan signal on each output to the laser's tuning elements (TE's): "TEactiveX" determines whether the output signal is scanned at all,

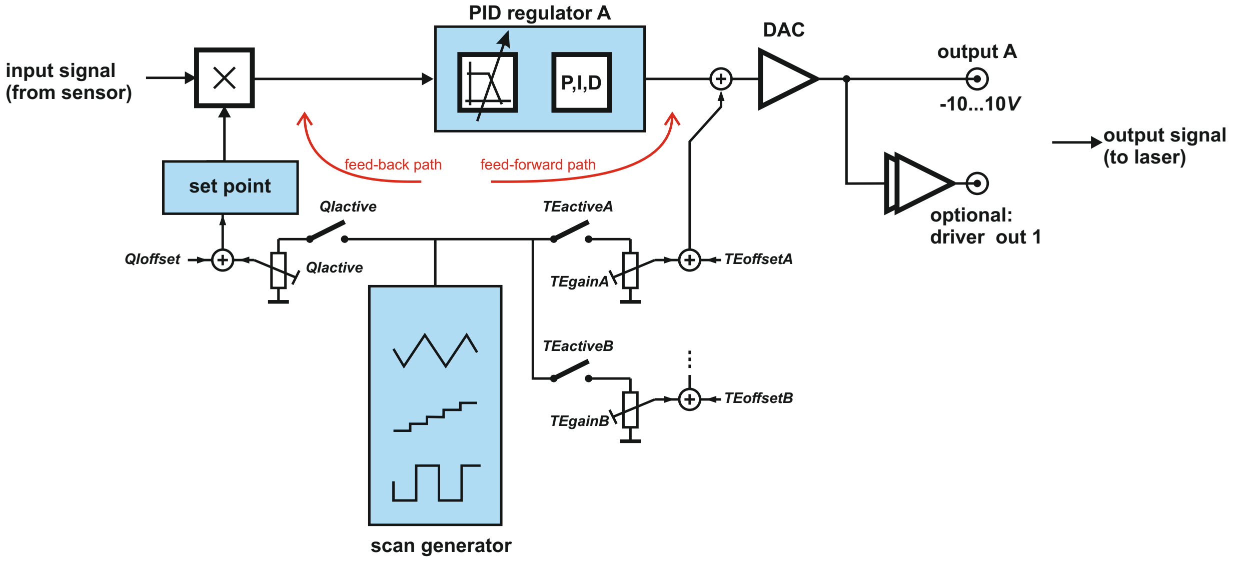


Figure 17: The scan generator acts on the frequency setpoint (feedback path) as well as on the outputs directly (feedforward path).

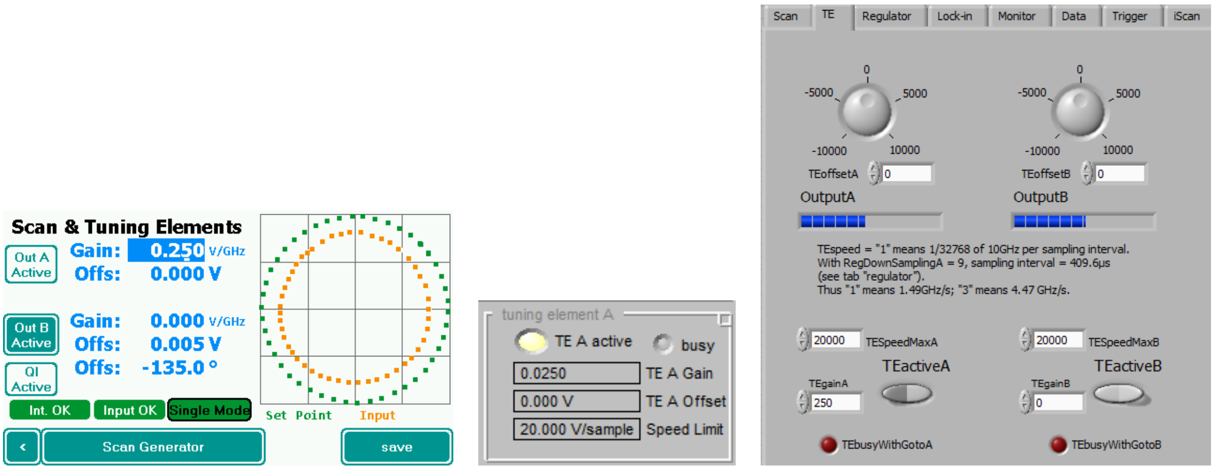


Figure 18: Tuning elements menu (left) and the corresponding GUI elements (right)

"TEgainX" is the conversion factor (from GHz detuning to volts) and "TEoffsetX" is a constant voltage offset applied to the output. Here "X" stands for the letter of A, B, C . . . of the respective output.

Upon delivery, the iScan is preset in a way that no scan signal is applied to the output (all TE parameters equal zero or 'off'). Before the feedback loop can be closed, the gains for all tuning elements should be set to approximately correct values. For this end, navigate to *Settings* → *Scan settings* → *Scan & Tuning elements* or localize the corresponding GUI elements according to fig. 18.

If the laser is to scan by the tuning element attached to either output A or B, the respective button "Out A active" or "Out B active" have to be pressed so that they are lit. If two tuning elements have to be scanned synchroneously (like current and piezo voltage in an ECDL), both outputs must be active. (Note: The button may have different names depending on the application.) Finally, the conversion factor from "GHz detuning" to "voltage applied to the output" has to be adjusted

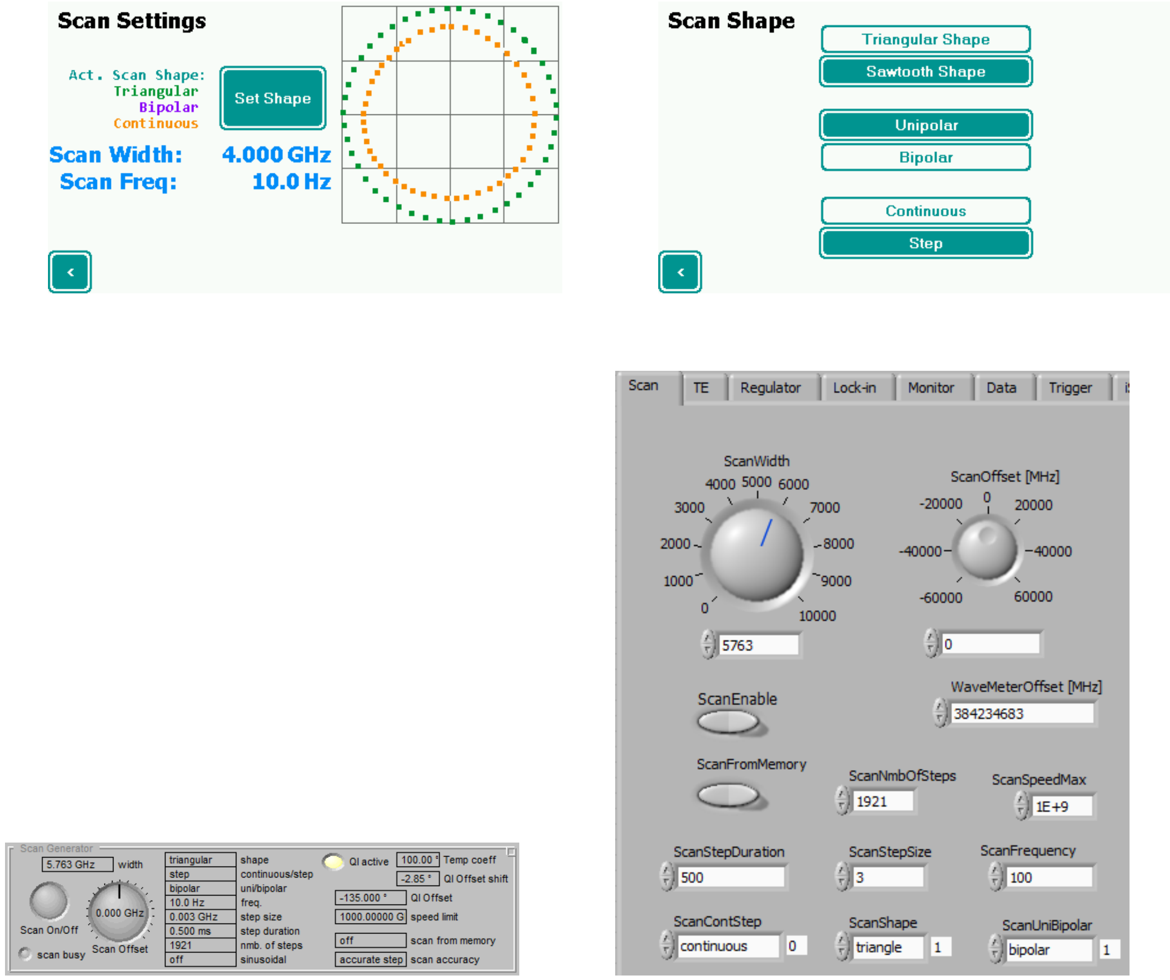


Figure 19: Menus "Scan Tuning elements" and submenu "Scan settings" as well as the corresponding GUI elements

as "Gain". Fig. 18 shows a situation with laser tuned via output A at a rate of 250 mV per GHz. Please note that also the sign of the gain values has to be correct. (If the laser is tuned by injection current or temperature, the gain signs must in most cases be negative, as an increase of these physical parameters makes the resonator longer and therefore reduces the optical frequency. For PZT tuning, the sign must be positive in most cases.)

Next, a scan has to be set up. The respective settings can be found in the "Scan settings" menu, which is a submenu of the "Scan and tuning elements menu". For a first adjustement, a continuous scan over a few GHz (approximately 1 FSR) should be set up. A scan frequency of 10Hz is reasonable, provided that the laser can scan at this speed. So set the parameter "Scan width" to a few GHz and "Scan frequency" to 10Hz (see fig. 19). If the latter parameter does not show up, enter the submenu "Scan shape" and set the shape to triangular/bipolar/continuous.(Stepwise scans are characterized by number of steps and their duration rather than the scan frequency. It is possible to adjust the signals with a stepwise scan, but for the "getting started", a continuous scan is more intuitve.)
Finally, start the scan by hitting the corresponding button on the home screen of the TFT or by clicking to the corresponding GUI element "Scan On/Off" or "ScanEnable".

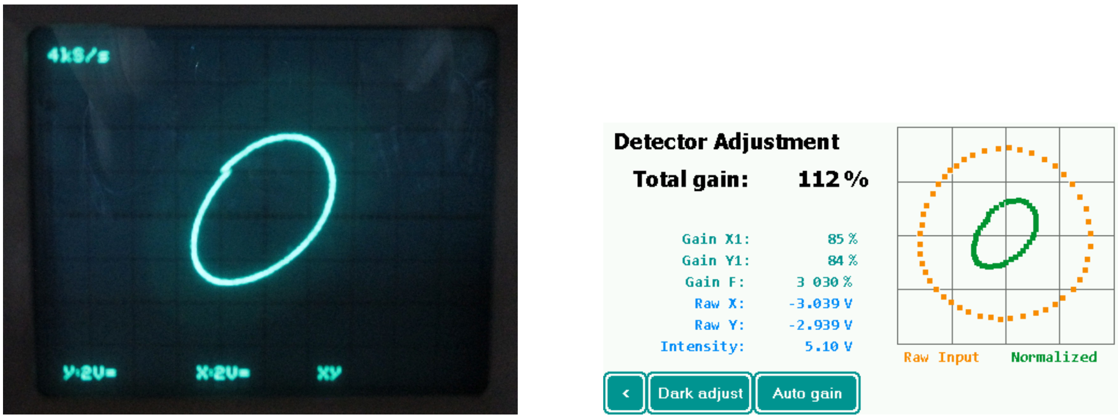


Figure 20: Raw quadrature signal on an oscilloscop (left) and on the TFT (right)

You may now observe the laser's frequency scan on a wavemeter. The scan range (covered frequency / wavelength interval) should be approximately the same as the scan width setting taken in the previous section. Otherwise, the tuning elements' gains should be adapted.

You can cross-check a proper setting of the gain watching the signal: The trace on the scope and the green dots in the "Detector Adjustment" that represent the raw input values form an ellipsis (see fig. 20). The orange trace on the TFT may deviate from the shape shown, as the input signals are not yet adjusted correctly. It is the goal of the next steps that the actual values (orange dots on the TFT) form a circle.

6.9.1 X and Y gain adjustment

Next, adjust the parameters "Gain X1" and "Gain Y1" so that the quadrature signal (which may well form an ellipsis rather than a circle) is centered about the origin of the oscilloscope screen as shown in fig. 20.

Note: The signal does not need to form a closed trace. A change of optical power in the sensor head during the scan will result in a change of the radius, thus turning the ellipsis into a spiral. This effect will be eliminated by normalization (division by the intensity) in the next steps.

Press <to return to the input adjustment menu. Switch the normalization on using the corresponding button. The normalized signals are displayed as orange dots on the TFT. You can as well display them on the oscilloscope by either changing the respective GUI elements Monitor X and Monitor Y, or by entering the Monitor menu and choosing "Raw and Normalized Input). With the latter choice, the DCU switches the monitor outputs quickly between both the raw and the normalized signals so that thy appear displayed simultaneously (see fig. 21) (You can achieve the same effect in the GUI by selecting raw X/Y for Monitor X/Y and "Norm X/Y" for "Chopper X/Y") Then adjust the parameters Gain X/Y, Offset X/Y and Phase so that the normalized signal forms a circle with 6V radius and its center at 0V.

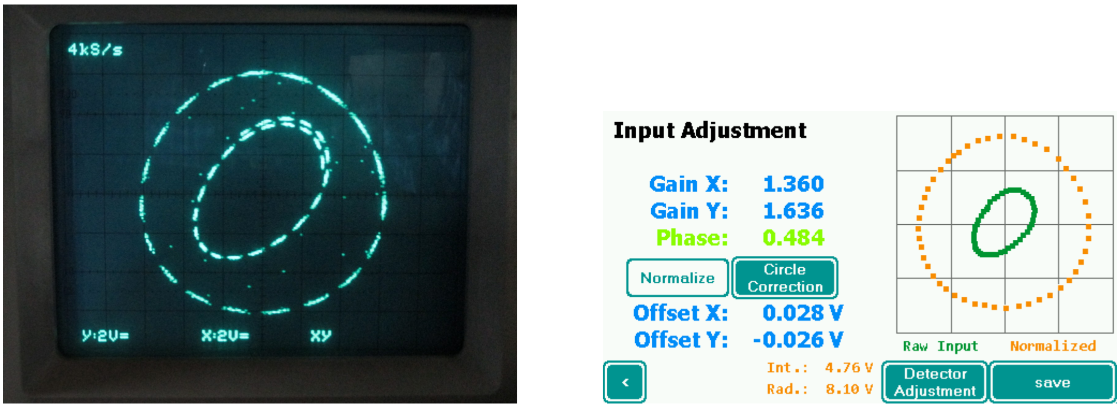


Figure 21: Raw (inner trace) and normalized (outer trace) input signals dislayed simultaneously on the oscilloscope by the chopper function as well as on the TFT. The outer signal trace is to be adjusted in terms of offset, amplitude and phase.

The signals should not exceed the range of $\pm 8\,\mathrm{V}$ to avoid distortion. The red LED "in clip" will be lit if the signal approaches the limits of $\pm 10\,\mathrm{V}$.

()If you cannot adjust the normalized signal to a circle, the laser is possibly not running in a single mode. Laser emission at multiple frequency results in a loss of coherence contrast and thus a reduced radius (see fig. 4 in chapter 1 for an extreme illustration). A careful adjustment of the tuning elements' gain and offset values might bring the laser back into single-mode operation.)

Sign check: As the frequency change of the laser is encoded in the angular coordinate of the quadrature signal, a rotation in positive (counterclockwise) direction should correspond to an increase in the optical frequency. In order to check this, return to the main menu (home screen) or localize the GUI elements for "Scan on/off" and "Scan offset". Switch the scan off — the trace on the oscilloscope should come to a halt now. Then change the "Scan offset" from 0 to 1 GHz, e.g.. The laser should react by a frequency change of +1GHz. If you find this is not the case (for example, by means of a wavemeter), reverse the signs of all active tuning elements' gains, see section 6.9. (If the laser is tuned by injection current or temperature, the gain signs must in most cases be negative, as an increase of these physical parameters makes the resonator longer and therefore reduces the optical frequency. For PZT tuning, the sign must be positive in most cases.)

Next check that when increasing the "Scan offset", the normalized signal rotates counterclockwise. If this is not the case, reverse the sign of the "Input Gain Y" and the "Phase" value.

Finally click to "save" on the TFT or on "Save to C" on the GUI to store the parameters to the non-volatile memory of the *iScan* device.

6.10 Taking the PID regulator into operation

The purpose of the *iScan* is to adjust the laser's optical frequency in a way that it steadily equals a preset target value. By changing (scanning) the latter, the laser is tuned while it remains locked. For the setup of the PID loop, reduce the scan width to a fraction of the FSR (a few 100 MHz, e.g.) and activate the scan.

When operating the *iScan* by touch panel, navigate to *Settings* → *Regulator A*. When using the Kangoo software, locate the respective GUI elements on the screen (fig. 22).

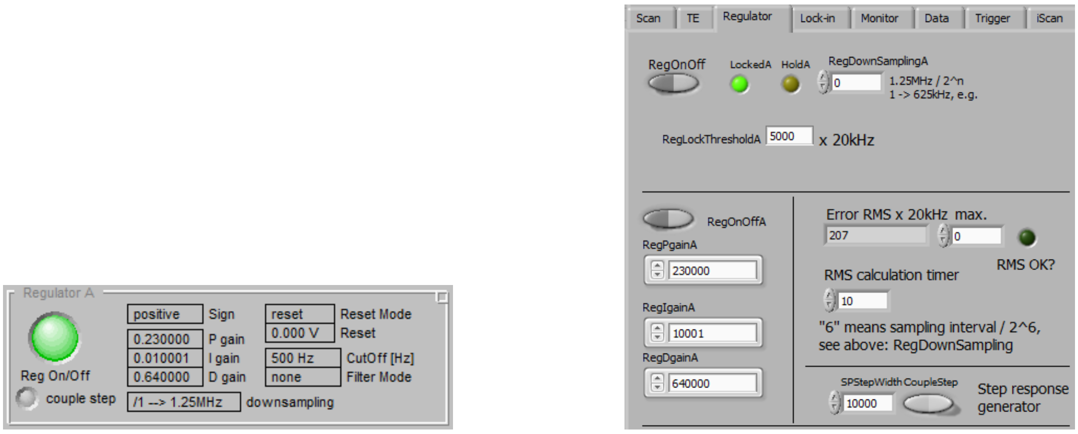


Figure 22: Regulator A adjustment screen and GUI (default settings)

It is helpful to watch the actual and the setpoint simultaneously on the scope: Enter the Monitor menu and choose "Set point and Normalized Input" so that these signals appear displayed simultaneously (see fig. 23) (You can achieve the same effect in the GUI by selecting "Setpoint X/Y" for "Monitor X/Y" and "Norm X/Y" for "Chopper X/Y".

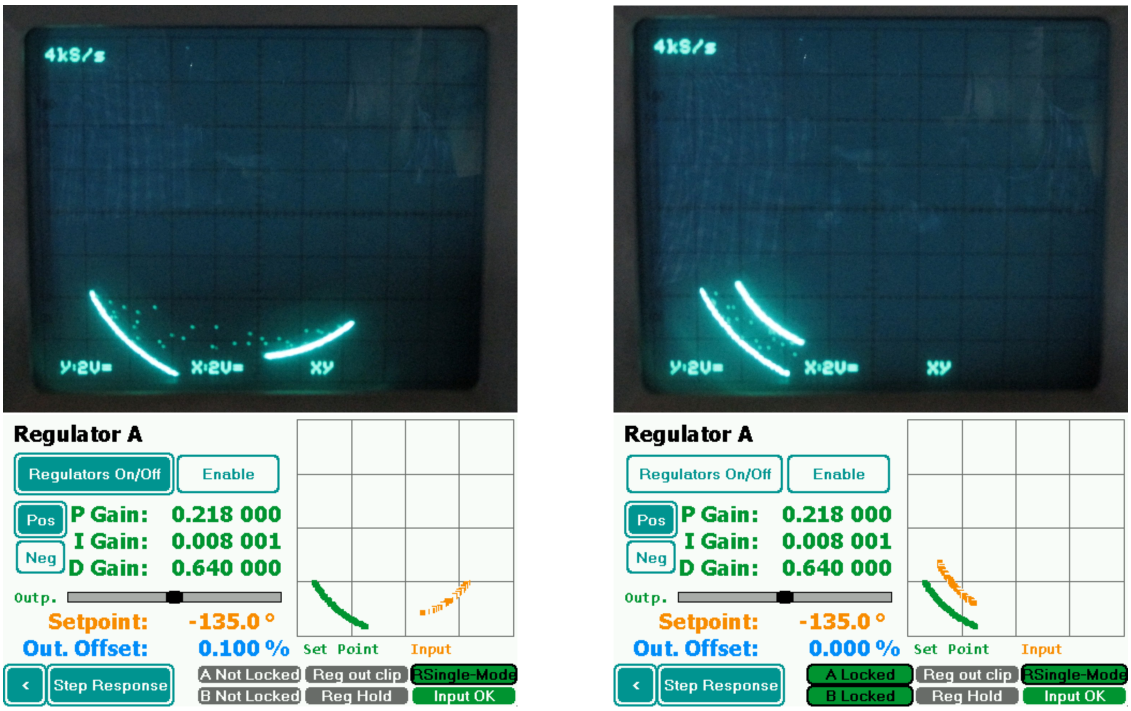


Figure 23: Normalized (inner trace) and setpoint (outer trace) signals dislayed simultaneously by the chopper function. The signals appear at different angles as long as the servo loop is not closed ("blind–flight scan, left hand side).

Remember to think in polar coordinates now: the momentary angle of the X,Y–position represents the laser frequency, while the (electronically normalized) radius is a measure for the coherence properties of the laser.

The outer trace (green on the TFT) has the shape of a circle (with 8V radius on the oscilloscope) and corresponds to the pair of FPGA-generated quadrature signals $\mathrm{X_S}, \mathrm{Y_S}$. The inner trace (orange on the TFT) corresponds to the normalized pair of interferometer signals X, Y already described in the previous section. Remember that its shape should form an exact circle (with 6V radius on the oscilloscope). (If the shape deviates from a circle, or if you are uncertain about this, follow the instructions given in section 6.9.1. Make sure the laser is scanning in a single-mode state and without mode hops.)

As long as the PID loop is not closed (regulator off), the setpoint and the actual values scan at different angles (fig. 23 left hand side). The reason that the actual value scans at all is the feed-forward to the output ("blind-flight" scan).

The PID adjustment starts with P=0, I=0.000001, D=0. Set the sign according to the direction of the actuator attached to output A: Usually, the regulator sign must be the same as the corresponding tuning element's gain sign. That is, if the optical frequency increases with increasing voltage, choose "positive" and otherwise "negative". Check that regulator A is enabled while regulator B is *not*.

Now watch the signal on the oscilloscope while clicking "Reg On/Off" and compare the observation with figure 23:

When the regulator is switched on, its output voltage shifts the optical frequency towards the setpoint. (If it is merely running away from the setpoint, the regulator sign is wrong. Just switch the regulator off, reverse the sign and switch on again.

Congratulations! Your laser is now locked (yet very weakly). You may proceed with section 6.11 to optimize the lock.

6.11 Optimizing the PID regulator

In the next steps, the feedback parameters P, I and D are optimized aiming at a fast response of the laser to a change of the setpoint. For this end, stop the scan. The traces on the oscilloscope will shrink down to dots. Enter the "Step response" menu which is a submenu to the regulator menu and hit "Add step". Alternatively, click "couple step" in the Kangoo GUI or in the calibration software.

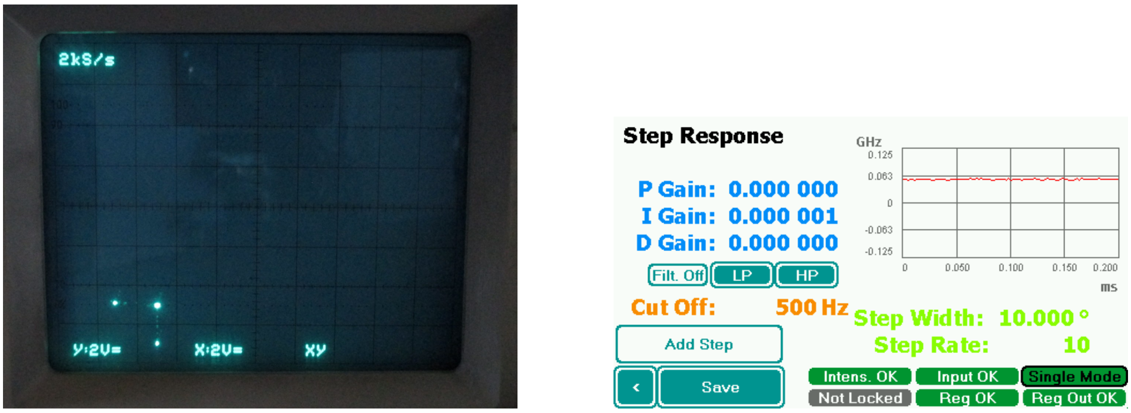


Figure 24: A square signal is added to the setpoint resulting in fast steps (outer trace on the oscilloscpe, left hand side). The actual value cannot yet follow the steps because the integrator is too slow (inner trace on left hand side, red trace on the TFT).

The "step" genenerator adds a square signal to the setpoint so that it perform steps. Each step results in a deviation between the actual and the target value. This difference (called error signal) is displayed as red trace in the "Step response" menu on the TFT (fig. 24).

It is the aim of PID optimization to let the error signal return to zero as quickly as possible. Increase the parameter "P gain" until you observe that the red trace approaches zero after the step, maybe with a slight overshoot (see fig. 25)

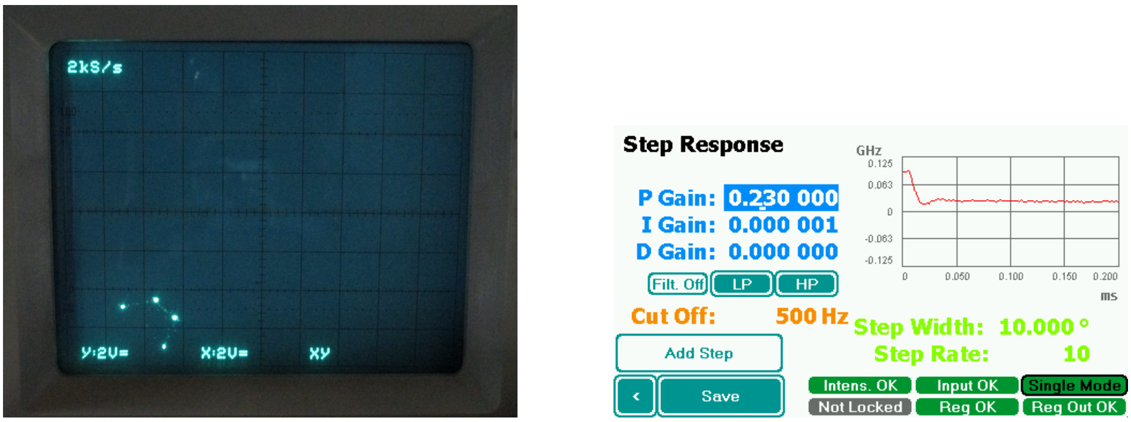


Figure 25: A square signal is added to the setpoint resulting in fast steps (outer trace on the oscilloscpe, left hand side). The actual value cannot yet follow the steps because the integrator is too slow (inner trace on left hand side, red trace on the TFT).

Next, increase the parameter "I gain" until the red trace converges to the base line (see fig. 26).

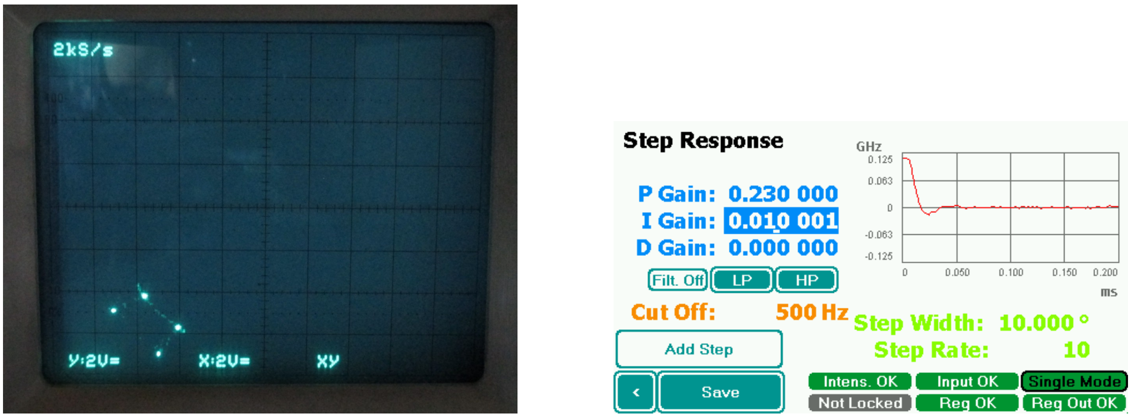


Figure 26: A square signal is added to the setpoint resulting in fast steps (outer trace on the oscilloscpe, left hand side). The actual value cannot yet follow the steps because the integrator is too slow (inner trace on left hand side, red trace on the TFT).

Overshooting or ringing is a typical response of inert actuators (like thermal actuators): They react with retardance to their control voltage, and they "brake" to late. This effect called "phase lag" can be counteracted by a differential gain in the feedback loop. So if you observe overshooting, increase the parameter "D gain" until the red line approaches the baseline smoothly
27).

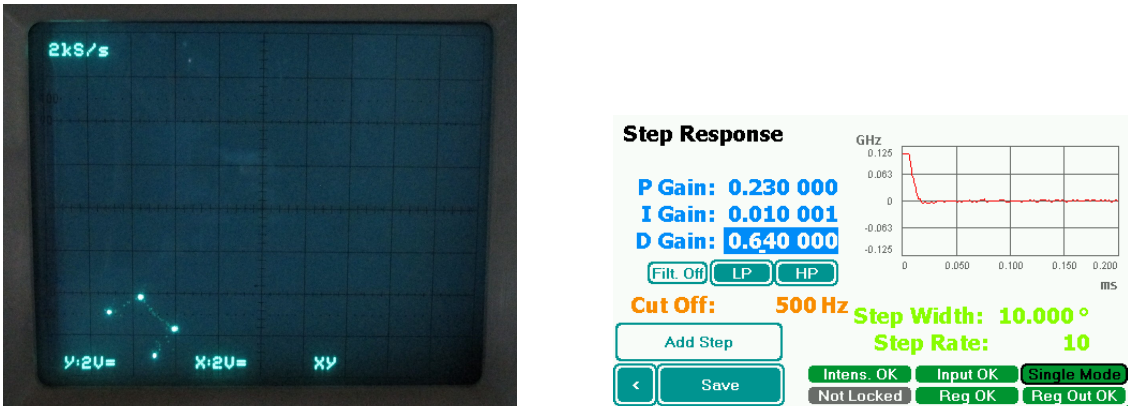


Figure 27: A square signal is added to the setpoint resulting in fast steps (outer trace on the oscilloscpe, left hand side). The actual value cannot yet follow the steps because the integrator is too slow (inner trace on left hand side, red trace on the TFT).

If the actuator tends to oscillate (so that the red line looks sinusoidal rather than getting flat), it has a (mostly mechanical) resonance. In such a case, engage the lowpass filter by hitting the button "LP" on the touch screen or by selecting the appropriate "filter mode" in the Kangoo GUI. Choose the corner (cut–off) frequency well below the resonance frequency. This will of course increase the response time of the feedback loop, but in turn you can increase the P, I and D gain so you get a higher precision at lower frequencies.

Congratulations! Your laser is now phase-locked with high quality!

iScan can indicate this success via the LED "locked". The criterion for the LED to turn from grey to green is that the regulator is active ("Regulator A enabled" and "Regulator On") *and* that the error signal does not fluctuate but in a small range around zero. The thresholds that define the "locked" range are somewhat arbitrary and have to be adjusted individually to the laser. For some lasers, the error signal fluctuates more than $\pm 10\%$ (of the available range of $\pm 10\mathrm{V}$), while other lasers are so stable that they cannot be considered "locked" when the error signal exceeds $\pm 1\%$. Therefore, simply set the value of " 'locked'–Threshold" to the smallest possible value that lets the LED appear continuously green when the PID regulator A is on and the lock seems stable to you. (You may gently knock on the table or on the laser case to see if the LED flickers due to the increased disturbance.)

Do not forget to click to "save" on the TFT or on "Save to C" on the GUI to store the parameters to the non-volatile memory of the *iScan* device.

If your laser is equipped with only one actuator, installation and set–up are now finished.
If you want to control your laser by *two* tuning elements, follow section 6.12 to learn how to engage the second PID loop.

6.12 Taking the PID regulator B into operation

If your laser is equipped with *two* tuning elements, you have to distinguish between the following cases:

1. Additive tuning: Either tuning element can tune the laser alone (possibly with different strokes and speeds). Therefore, the scan signal can be applied arbitrarily to either or both TEs. The resulting frequency change is the sum of both tuning effects.
   Example 1: A DFB laser diode tunes with change of injection current as well as chip temperature.
   Example 2: Often Ti:Sapphire are equipped with a small and a large piezo actuator ("tweeter" and "woofer").

2. Parallel tuning: Both tuning elements have to be scanned synchroneously with suitable amplitudes. Sometimes a mismatch of the tuning rates results in mode-hops.
   Example 1: An extended cavity diode laser (ECDL) is tuned by piezo (for the external cavity length) and injection current of the laser diode (for the chip's cavity length).
   Example 2: Ti:Sapphire lasers often have frequency selective etalons in their resonator, which have to be tuned along with the cavity length.

Depending your situation choose either of the following subsections to take the regulator B for the second tuning element into operation.

6.12.1 Regulator B for an additive tuning element

When two tuning elements control the laser frequency in an additive manner, typically one of them has a fast response but small stroke, while the other one is slower but has large stroke (large control range). The following explanation is based on the assumption that the PID loop for output A has already been optimized for the fast actuator as described in the previous sections. Connect the slow actuator to output B.

When the PID for output A is working, it keeps the error signal at its setpoint (thus the laser frequency at the target value) by applying the appropriate output voltage to the actuator. Therefore, if the setpoint is zero, the error signal will be zero, too, while the output voltage will be stable at a certain value that is typically different from zero. In contrast, if the laser drifts over time, the regulator will have to compensate for that by a continually increasing/decreasing the output voltage. However, if the latter reaches either limit at $(+10\mathrm{V})$ or $(-10\mathrm{V})$, the regulator loses the lock. In order to prevent this, the large–stroke actuator can be used to support the fast actuator. For this end, the second PID regulator uses the actual output A voltage as error signal (see fig. 2)and drives its own output voltage (and thus the connected large–stroke actuator) in way that the error signal (and thus the fast actuator) can return to the center of its operating range.
For the set-up and optimization of regulator B it is necessary to monitor its error signal and the regulator output signal simultaneously on the oscilloscope. For this end, set "Monitor X" to "Reg out A" (as this is the error signal for regulator B) and "Monitor Y" to "Reg out B". (Refer to the previous sections to learn how to select monitor signals.)
When operating the *iScan* by touch panel, navigate to the "Regulator B" menu (see fig. 28) by pressing *Setting* → *Regulator B*. When using the Kangoo software, locate the respective GUI elements on the screen.

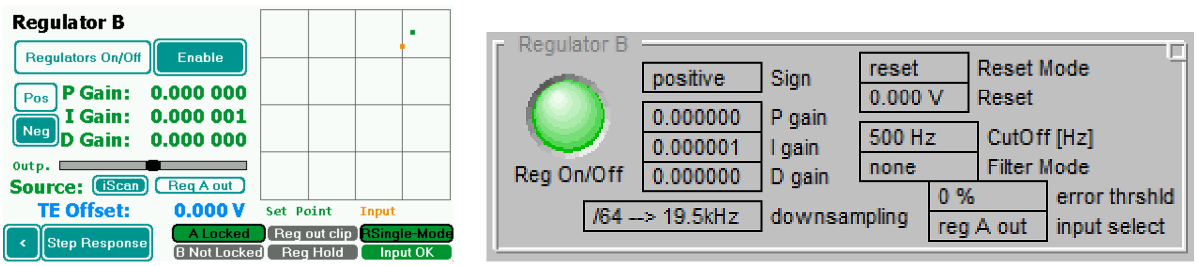


Figure 28: Regulator B adjustment screen and GUI (default settings). Note that the LED "A locked" is green as a prerequisite for the operation of regulator B.

First of all, select "Reg A out" as source (input signal) for regulator B. As regulator B is supposed to work very slowly (only for drift compensation), we recommend to reduce its sampling rate by some factor (64, e.g., see figure 28). The gains for P and D can remain at zero while the I gain must be set to the smallest possible value 0.000001.
If both actuators work in the same direction, the sign must be set positive ("Pos."). This is typically the case if the actuators consist of resonator end mirrors glued on top of a PZT, because then a positive voltage will result in a smaller resonator length (and thus higher rep rate) for both PZTs. Similarly, a positive sign is appropriate for DFB lasers tuned by current and temperature, as both effects work in the same direction. If the effective direction is opposite for both actuatuors, the sign must be set negative ("Neg.").
It is furthermore necessary that the regulator A is enabled and "on", and that its error signal is stably close to zero. This condition is indication by the LED "A locked" being lit green. If regulator A is on, but the LED is not green, follow section 6.11 to optimize the regulator A and then adapt the parameter "locked threshold" (only accessible via PC, variable name "RegLockThresholdA") so that the LED is sufficiently tolerant.
Now watch the signal on the oscilloscope while clicking "Reg On/Off" and compare the observation with figure 29:
At the beginning the "Reg out A" signal is at a certain voltage as described before, while "Reg

out B" is at zero. When the regulator is switched on, "Reg out B" starts to increase (or decrease) (2). "Reg out A" in turn converges to zero, and the regulator B output voltage comes to rest at a finite level. This only works if the sign is correct — otherwise it will accelerate the phase slope so that both voltages diverge towards $\pm\infty$ until they come to stop at $(+10\mathrm{V})$ or $(-10\mathrm{V})$. This is of course not intended. If you observe this, switch the regulator off, reverse the regulator B sign and try switching on again.
From now on, every movement of actuator A will be counteracted by a slow movement of actuator B, so that in the time average, the output A voltage stays at zero (meaning that the actuator A stays in the center of its range). Thus, fast fluctuations of the repetition frequency and pulse phase will be compensated for by actuator A, the long term drift by actuator B.

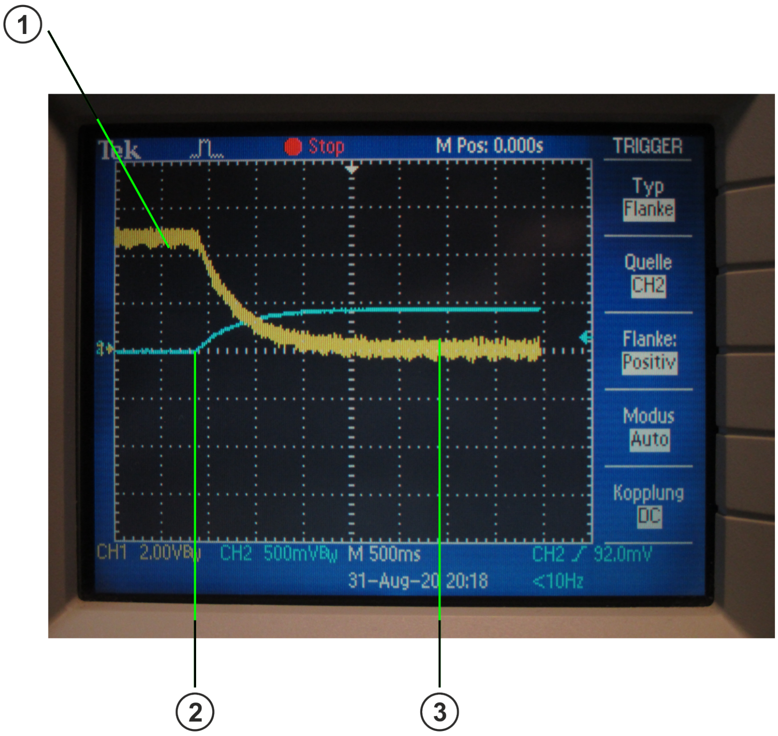


Figure 29: "Reg out A" and "Reg out B" signal when the regulator is switched on

If for any reason, regulator A unlocks, regulator B will be set on "hold" state, that is suspend working until regulator A signalizes "locked" again. This can happen for example if the slow actuator (at output B) changes the laser frequency so much that it drives the laser in a multi–mode state. If this happens, the feedback system hangs up, because regulator A signalizes "unlocked" and regulator B remains in that disadvantegous position. In this case, hit the main regulator button (this turns to both regulators off), adjust the "TEoffsetB" of regulator B to get the laser running single–mode, and try switching on again. Also if regulator B is too slow so that regulator A reaches either limit of its output range, regulator B will hold on. If this happens, the speed of regulator B should be increased, either by choosing a higher "I gain" or by selecting a lower "Downsampling" factor.

6.12.2 Regulator B for a parallel tuning element

When two tuning elements control the laser frequency in a parallel way, typically they have to be adjusted individually in terms of their offset (control voltage at scan offset zero) and gain (change

of control voltage per GHz detuning). See section 6.9 for details.
Oftentimes one of the tuning elements has a faster response than the other one (laser diode current vs. piezo elongation, e.g.). If this is the case, optimize the PID loop for output A for the slow (!) actuator as described in the previous sections, using the regulator's input filter to limit the control bandwidth to a range safely covered by the actuator. (For a piezo actuator, a few hundred Hertz is often good value.)

When the PID for output A is working, it keeps the error signal at its setpoint (thus the laser frequency at the target value) by applying the appropriate output voltage to the actuator. However, due to the limited bandwidth fpr regulator A, the error signal shows fluctuations at higher frequencies which regulator A cannot compensate for . In order to support regulator A, the second PID regulator uses the same error signal, but uses a highpass filter to separate the higher from the lower frequencies (see fig. 2, switch at pos. 2).

Connect the fast actuator to output B. When operating the *iScan* by touch panel, navigate to *Settings* → *Regulator B*. When using the Kangoo software, locate the respective GUI elements on the screen (fig. 30).

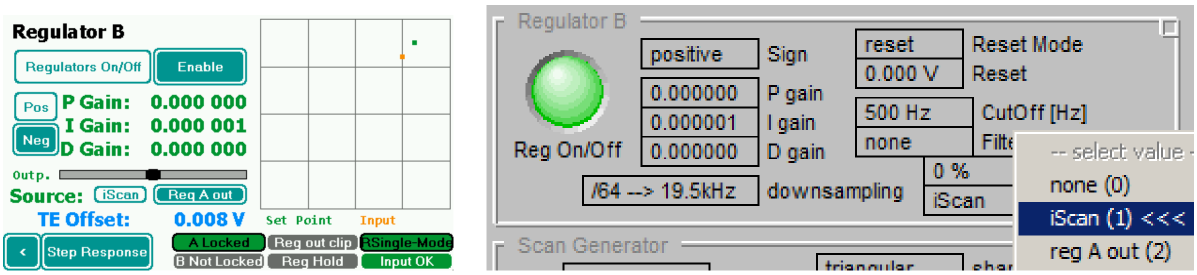


Figure 30: Regulator B adjustment screen and GUI (default settings). Note that the LED "A locked" is green as a prerequisite for the operation of regulator B.

First of all, select "iScan" as source (input signal) for regulator B. As regulator B is supposed to work for short–term fluctuations, keep "I gain" at zero all the time. Set the gains for P and D to zero for now and enable the regulator B. The LED "B locked" will probably be lit, because the regulator A is already keeping the error signal close to zero. Enter the "Step response" menu or locate the respective elements in the GUI. Set the filter to "HP" ("highpass") and choose the cut–off frequency to the same value as you did for the lowpass filter in regulator A. Hit the button "Add step" on the TFT or click "couple step" in the Kangoo (regulator A section) to engage the step generator. Iteratively increase the parameters "P gain" and "D gain" to achieve the fastest response to the step. This procedure is roughly the same as described in section 6.11 for regulator A.

6.13 Loss of input signal and hold mode

The *iScan* sensor head requires a minimum optical power for proper operation. If the "Intensity" value falls below a userdefinded "IntensityThreshold", the regulators are put on hold. That is, the output is kept constant at its actual value until the intensity is large enough again. Typically, the threshold is set to 1 V so that the intensity can range from there up to 10 V. The radius of the normalized signal will remain almost constant due to the normalization (division of all signals by the intensity).

Despite that, the radius of the normalized signal can decrease if the laser is running on multiple frequencies (multi–mode state). In order to prevent unsuitable reactions of the regulator, you can set a minimum radius threshold. A decrease below that will also put the regulators on hold and the DCU will signalize a multi–mode event.

Similarly, a threshold can be defined to distinguish a mode-hop from regular scanning. The phase difference of subsequent samples is compared to that value. If the jump is larger, the DCU signalizes a "mode hop".

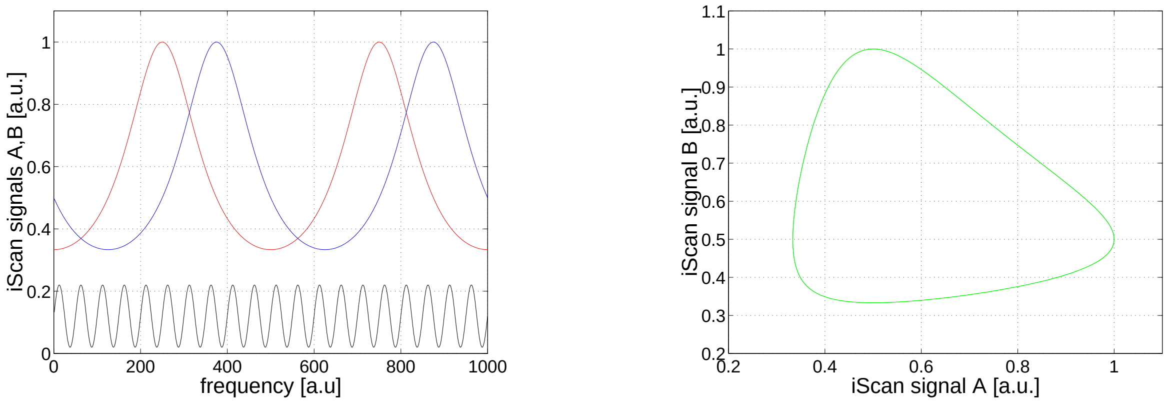


Figure 31: Distortion of the *iScan* sensor signals.

7 Calibration and Linearization

The *iScan* uses the phase of a quadrature signal as a measure for the frequency change of the laser. However, the assumed linear relationship is only an approximation. In general, the x–y signals are better described by the Airy formula than by simple sine/cosine functions (fig. 31, upper traces on the left hand side, x–y trace on right hand side). If a high precision is required, one has to account for the distortion of the phase–frequency relation. For this end, the *Linearization Kit* contains a marker etalon that provides fringes at a higher resolution than the *iScan* does (fig. 31, lower trace on the left hand side). In order to achieve a linearization, the laser is scanned over 1 free spectral range (FSR) of the iScan, and the fringes obtained from the marker etalon are recorded. The information about the nonlinearity is extracted from the marker signal and stored into the *iScan* DCU as a look–up table for the regulator setpoint.

The linearization process is executed in a LabView based PC program. Install and start the program according to chapter 6. In the tab "operation" put the switch "Linearize" to on (fig. 32). If a spectroscopy unit is attached to the *iScan* DCU, also turn on "Use *CoSy* . . . ".

Click to "calibrate" to start the calibration process. When using the spectroscopy unit, a "Target frequency" has to be chosen sufficiently close to a suitable line in the hyperfine spectrum of an alkali metal vapor (Rb, Cs or K). The program will run through 4 steps: Adjustment of circle parameters (gain, offset and phase), linearization, search for the doppler–broadened spectral line of the alkali vapor, search for the hyperfine line (as indicated in the GUI as "Ref line frequency", fig. 32). After

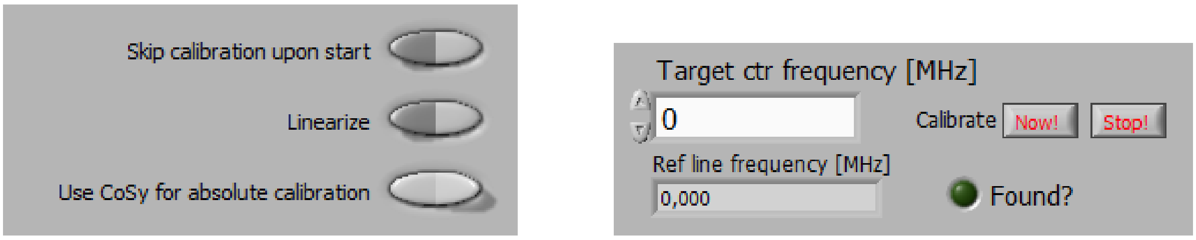


Figure 32: These switches determine what sort of calibration is done (left). Click "calibrate" to start the linearization process.

the calibration process, the laser will be locked at the target frequency.

7.1 Signal monitor

7.1.1 Analog monitor signals

iScan provide access to several internal signals. Although the signal processing is purely numerical, the monitor picks intermediate calculation results and reconverts them into analog signals by means of D/A converters so that the user can probe them with an oscilloscope just as if he was checking an analog circuit.
The following signals can be selected for probing through the Monitor X and Monitor Y outputs. The numbers correspond to the value of the parameter Monitor1Select or Monitor2Select, resp..

Value	**Name**	**Description**
0	off	Monitor output voltage = 0V const.
1	Raw x	Copy of sensor output signal (x component of the quadrature signal, pin 1 of the HD15 connector)
2	Raw y	Copy of sensor output signal (y component of the quadrature signal, pin 2 of the HD15 connector)
3	Intensity	Copy of sensor output signal representing the optical power
4	F	Copy of auxiliary sensor output signal (used for fiber marker etalon, e. g.)
5, 6	Norm X, Y	X, Y component of the normalized (size adjusted) quadrature signal
7	Error	Deviation of the measured phase (of the input quadrature signal) from the set point.
8	Reg out A	Output signal of PID regulator A N. B.: This signal covers a range of -10V to +10V, independent of the actual setting of the regulator output range (parameter RegOutRangeA)
9	Reg out B	Output signal of PID regulator B N. B.: This signal covers a range of -10V to +10V, independent of the actual setting of the regulator output range (parameter RegOutRangeB)
10	Output A	Copy of the signal on the "Output A" BNC connector. When using a high voltage (piezo) amplifier, the voltage range of -10V to +10V corresponds to 0 to 150V at the amplifier output.
11	Output B	Copy of the signal on the "Output B" BNC connector. When using a high voltage (piezo) amplifier, the voltage range of -10V to +10V corresponds to 0 to 150V at the amplifier output.
12...15	Measurement input a...d	(Optional: Copy of the signals applied to measurement inputs, from the spectroscopy unit *CoSy*, e.g.))
16	Normalized scan	Signal proportional to the scan. The voltage range -10V to 10V always corresponds to the full scan range, independent on the actual setting of the parameter ScanWidth.

17, 18	Set point X, Y	Quadrature signal generated from the phase set point. The purpose of this signal is only visualization of the scan phase.
19	Radius	Actual radius of the normalized (size adjusted) input quadrature signal (an indicator for the mode purity of the laser spectrum)
20	Phase	Actual phase of the normalized (size adjusted) input quadrature signal. The signal voltage range -10V to +10V corresponds to -180 to +180, unless the parameters NormPhaseOffset and NormPhaseGain are changed.
21	LIA out A	Output of lock-in amplifier A
22	LIA out B	Output of lock-in amplifier B
23	Interferometer X	External interferometer signal (quadrature component X)
24	Interferometer Y	External interferometer signal (quadrature component Y)
25	Interferometer counter	External interferometer signal (increment counter)
26	Error RMS A	Standard deviation of the error signal of regulator A, integrated over 1 period of the step signal
27	Error RMS B	same for regulator B
28	LI reg out A	Output of lock-in regulator A
29	LI reg out B	Same for lock-in regulator B
30	(Frequency)	(reserved: Period time of the input signal (reciprocal of the scan speed)).

Note: Values from 33 to 52 are available in twin systems, i. e. systems that handle two *iScan* sensor heads (in a cw THz system, e.g.).
Note: The monitor is capable of displaying two signals virtually simultaneously by quickly switching between two values. To activate this, set the parameters *Monitor1Chopper* or *Monitor2Chopper* to a value according to the above table. (A value of 0 for the chopper will put the switching off.)

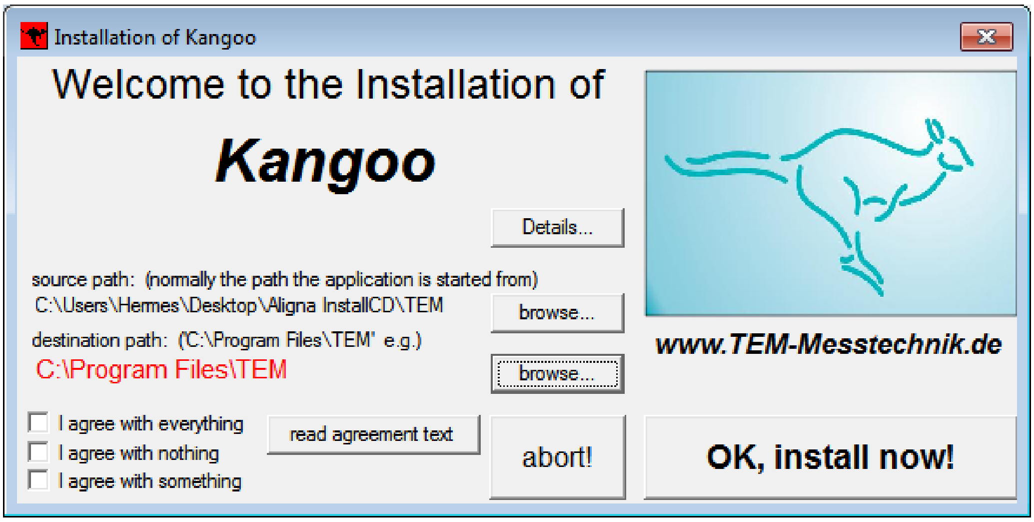
7.1.2 TTL output

The "Trigger" BNC connector provides a digital TTL (0 to 5V) square output signal that synchronizes the oscilloscope display with the processes inside the *iScan* , such as scan, step response and others. It is therefore recommended to connect this output to the trigger input of the oscilloscope.

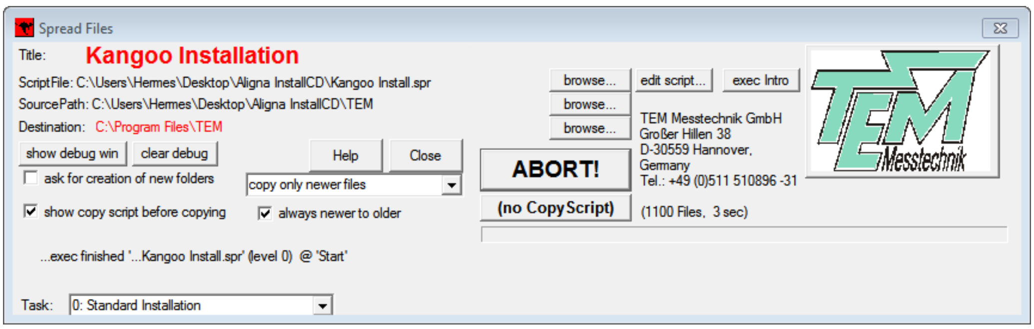
8 Software Installation

8.1 Installation of the Kangoo Software

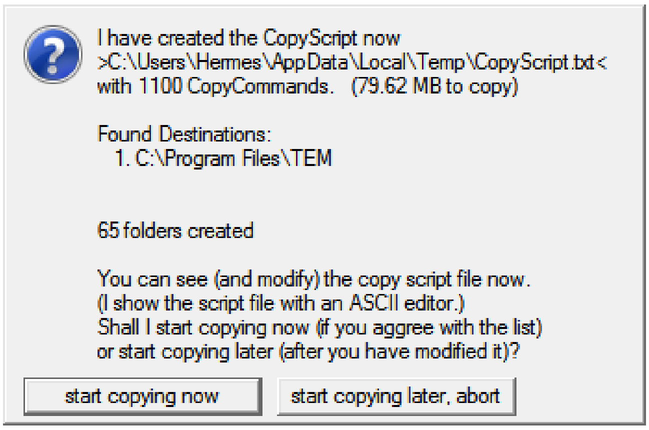
To install the Kangoo software, start the program Install.exe in the root directory of the installation CD or USB memory stick, resp.. The installer will show a welcome screen with several options.

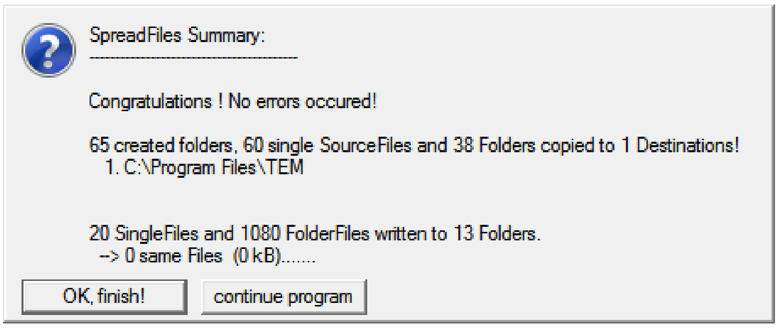


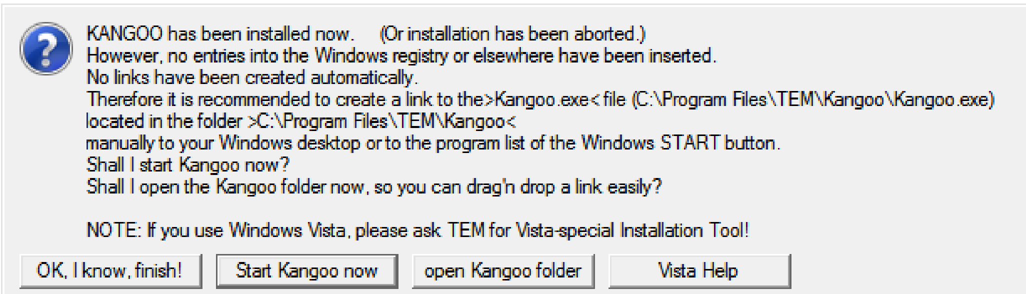
The default options should work fine, with the possible exception of the section "Destination Path", where the destination directory is specified. The standard directory is "TEM" in the "Program Files" folder. On Windows Visa or Windows 7 systems, please avoid the "Program Files" folder and choose and a different path, for example "C:/TEM". The button "OK, install now!" starts copying all required files from the source path to the destination path. During the installation procedure, the installation program checks all required files.



The program then creates a list of file copy commands. When this list is complete, you can check the list and start the copy procedure.







8.2 Installation of LabView Drivers

To install LabView demo VIs and their Sub-VIs, simply copy the content of the folder /TEM/LabView of the installation CD or USB memory stick, resp.., to your local LabView folder.
Please note that the NI-VISA package is required, which can be downloaded from the National Instruments web site.

8.3 Installing the USB Drivers

Typically, when the USB connection between the micro-controller and a PC is first made, Windows will open the Found New Hardware Wizard. Here, choose to install drivers from a user-specified location. The necessary driver file is located in the directory "TEM/Service/USB Driver" in the Kangoo installation directory (or on the install CD or memory stick). The Hardware Wizard will now finish the installation and no further configuration will be necessary.
Once the installation is complete, Windows will assign a COM-port. To find out which COM-port has been assigned, check for a new entry in the section "Ports (COM & LPT)" of the device

manager. The device will appear as "TEM uC Virtual Com Port" in the device manager of your computer (see figure 33).

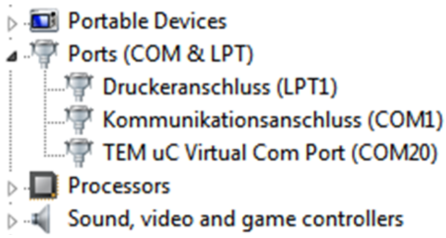


Figure 33: TEM COM Port in the device manager

8.4 Upgrading the Firmware

Please contact TEM Messtechnik for details about firmware upgrades.

9 Communication interface

9.1 Communication syntax

The communication between PC and microcontroller is carried by an ASCII-encoded stream of characters. (Exceptions are sometimes made in order to achieve fast binary data transfer.) The stream is structured in lines, the ends of which are marked by ASCII 13 (carriage return), followed by ASCII 10 (line feed).

Lines can be sent to the microcontroller (and in turn received from the μ)C by:

- entering them literally in the COM window of *Kangoo* or another terminal such as Microsoft HyperTerminal
- application programs such as *Kangoo* or LabView "Virtual Instruments"
- user-written programs, using languages like VB (Microsoft Visual Basic), C/C++, Delphi, etc. with help of COM procedures.

Both the microcontroller and the PC may send lines at any time. Please note that the microcontroller sometimes sends information without "being asked for". This means that the line received by the PC right after a query does not necessarily contain the answer to the query. Therefore a communication routine has to be programmed to catch all incoming lines and to parse them for the information of interest: Every single line has to be interpreted by the respective receiver.

An ASCII 39 (apostroph) character denotes a comment: the apostroph and all subsequent characters are deleted before the evaluation of the line.

The microcontroller distinguishes between "commands" and "variable assignments".

If the line does *not* contain an equal sign, the microcontroller interpretes it as a "command line". Tokens within the command line have to be separated by ASCII 32 (space) characters. The first token is taken for the command name, all further tokens are parameters to the command.

Example: If the microcontroller receives

`help`$\langle CR \rangle$

it will send a list of available commands to the PC.

Example: If the microcontroller receives

`help hello`$\langle CR \rangle$

it will send information about the command "hello", if available. In this case the token "hello" is a parameter that is handed over to the command "help".

If the line contains an equal sign (not preceeded by a space!), followed by a value, it is interpreted as a variable assignment.

Example: If the microcontroller receives

`CutOff= 1000`$\langle CR \rangle$

it will set the value of "CutOff" to 1000 and echo the value:

`CutOff= 1000`$\langle CR \rangle$

An ASCII 92 (backslash) at the beginning of the line suppresses the echo.
Example: If the microcontroller receives

`\CutOff= 1000`$\langle CR \rangle$

it will set the value of "CutOff" to 1000 and *not* echo the value, unless the value was not accepted. (In that case the echo will tell the actual value.)

If the rest of the line (after the equal sign) does not contain a value, the microcontroller responds telling the actual value. (This is a query for a value.)

Example: If the microcontroller receives

`CutOff=`$\langle CR \rangle$

it will send back

`CutOff= 1000`$\langle CR \rangle$

A complete list of variables and their values can be obtained by sending the command "vardump":
If the microcontroller receives

`vardump`$\langle CR \rangle$

it will echo one line for each available variable, in the style

$\langle variablename \rangle$= $\langle value \rangle\langle CR \rangle$

9.2 Variables

The following tables lists the most important operational parameters (stored as "variables" in the microcontroller). A complete list of variables and their values can be obtained using the command "vardump" (see section 9.1).

9.3 Input settings

Parameter name	Default value	Description	Access mode
RawX	0	Sensor signal x	Read-only
RawY	0	Sensor signal y	Read-only
Intensity	0	Sensor signal intensity, representing the optical input power	Read-only
Pin4HD15	0	Auxiliary sensor signal (used by fiber marker etalon, e.g.)	Read-only
DetectorTotGain	10000	Adjusts sensitivity of all sensor signals	
DetectorX1Gain	10000	Adjusts sensitivity of sensor signal component x	
DetectorY1Gain	10000	Adjusts sensitivity of sensor signal component y	
DetectorIGain	10000	Adjusts sensitivity of the intensity sensor signal (This should be always 100% - use DetectorTotGain to adjust the overall sensitivity)	
DetectorFGain	10000	Adjusts sensitivity of the auxiliary sensor signal component	
DarkAdjustA	0	Constant offset subtracted from input x ADC value.	
		Adjust this value only in absence of an input signal (laser off, e.g.).	
DarkAdjustB	0	same for input y ADC.	
DarkAdjustC	0	same for intensity input ADC value	
InClip	0	Flag = 1 if any input signal out of range	Read-only
IntensityThreshold	0	Regulators are put to hold whenever the intensity signal drops below this value (signalling "laser is off")	
LowIntens	0	Flag = 1 if the intensity voltage falls below "Intensity threshold"	

9.4 Quadrature signal adjustment and analysis

Parameter name	Default value	Description	Access mode
InputOffsetX	0	Horizontal offset of the normalized quadrature signal	
InputOffsetY	0	Vertikal offset of the normalized quadrature signal	
InputGainX	0	Horizontal amplitude of the normalized quadrature signal	
InputGainY	0	Vertikal amplitude of the normalized quadrature signal	
InputPhase	0	Shape adjust of the normalized quadrature signal	
InputNorm	1	Enables normalization (division of x and y by intensity – should always be "on")	
Circle	0	Integer part of phase value (multiples of 360).	Read-only
Frequency	1	Revolution frequency of the input quadrature signal. Clockwise revolution will result in negative frequency values.	Read-only
MaxFrequency	100 000	Search will not stop if frequency exceeds this value ("FreqOK" false)	
FreqOK	0	Flag = 1 if Frequency ¡ MaxFrequency	Read-only
Radius	0	Momentary radius of quadrature signal	Read-only
MinRadius	1000	Regulators are put to hold whenever the radius drops below this value ("interference contrast low", due to multi-mode state of the laser, e.g..)	
MaxRadius	9500	Regulators are put to hold whenever the radius exceeds this value	
RadiusOK	0	Flag = 1 if MinRadius ¡ Radius ¡ MaxRadius	Read-only

9.5 Monitor settings

Parameter name	Default value	Description	Access mode
Monitor1Select	5	Selection of probe signal for Monitor X output. See monitor description	
Monitor1Chopper	0	Second probe signal for Monitor X output. If not off, the monitor output quickly switches between the signal selected here and by Monitor1Select, thus virtually displaying both signal simultaneously on the oscilloscope.	

Monitor2Select	6	Selection of probe signal for Monitor Y output see above.	
Monitor2Chopper	0	Second probe signal for Monitor Y output see above.	
NormPhaseOffset	0	Shifts the phase signal probed by the monitor (when set to signal no.20)	
NormPhaseGain	1	Scales the phase signal probed by the monitor (when set to signal no.20)	
AutoNormPhase	0	If set to 1, the parameters NormPhaseOffset and NormPhaseGain are adjusted automatically to ensure +/-10V correspond to +/-180	
NormX	0	Direct access to monitor values.	Read-only
NormY	0	Direct access to monitor values.	Read-only
Radius	0	Direct access to monitor values.	Read-only
Phase	0	Direct access to monitor values.	Read-only
SetPointPhase	0	Direct access to monitor values.	Read-only
Error	0	Direct access to monitor values.	Read-only
RegOutA	0	Direct access to monitor values.	Read-only
RegOutB	0	Direct access to monitor values.	Read-only
OutputA	0	Direct access to monitor values.	Read-only
OutputB	0	Direct access to monitor values.	Read-only
CircleState	0		Read-only

9.6 Regulator (servo loop) settings

Parameter name	**Default value**	**Description**	**Access mode**
RegOnOff	0	General enabling of all regulators	
RegOnOffA	1	Setting this value to 0 makes servo loop A inactive.	
RegOnOffB	0	Setting this value to 0 makes servo loop B inactive.	
RegSignA, RegSignB	0	Sign of regulator loops A, B.	
RegPgainA, B	0	Regulator A, B: P gain	
RegIgainA, B	1	Regulator A, B: I gain	
RegDgainA, B	0	Regulator A, B: D gain	
RegGainReductionA, RegGainReductionB	100000	Softstart percentage of regulator A, B (100 000 = no soft start)	

RegOutRangeA, B	100000	Voltage range that can be addressed by regulator A, B (before high voltage amplifier, if this is present)	
RegOutputOffsetA, B	0	Center of regulator A, B output range	
RegResetModeA, B	1	Behavior of the regulator output voltage when the regulator is off (0: hold, 1: go to RegResetValueA, B)	
RegResetValueA, B	0	Value of the regulator's output voltage when the regulator is off.	
RegLockThresholdA, B	5000	Threshold for qualifying a lock "stable", see LockedA, Locked B	
RegErrorThresholdA, B	0	Regulator remains on hold if the error signal is within +/- RegErrorThreshold.	
ErrorMeansA,B	0	RMS of the error signal, averaged over one period of the step response signal	Read-only
RegMeansThresholdA, B	0	See above: RegLockThresholdA, B	
MeansOKA, B	0	Flag set to 1 if error RMS (parameter ErrorMeansA, B) ¡ RegMeansThresholdA, B	Read-only
LockedA, B	0	Flag is set to 1 if the corresponding regulator is active and its error signal is within the range +/- ReLockThreshold AND ErrorMeans is within the range +/- RegMeansThreshold.	Read-only
RegOutRangeA, RegOutRangeB	100000	Percentage of output range that can be addressed by regulators A, B	
RegResetValueA, RegResetValueB	0	Value of the regulators' A, B output when the regulator is off.	
HoldA, B	0	Flag is set to 1 if the regulator is put on hold.	Read-only
OutClipA, B	0	Flag is set to 1 if the regulator output reaches its limit	Read-only

9.7 Scan settings

Parameter name	**Default value**	**Description**	**Access mode**
Scan (timing shift) settings			
ScanEnable	0	General on/off for the scan generator	
ScanWidth	1000	Total scan width (max min value)	
ScanOffset	0	Center value of bipolar scan; start value for unipolar scan	

ScanReady	0		
ScanNmbOfSteps	10	Number of steps in a stepwise scan.	
ScanContStep	0	Set to 0 for a linear (continuous) and to 1 for a stepwise scan.	
ScanUniBipolar	1	Set to 0 for scan that addresses only positive (or only negative) output values. Set to 1 for a scan that covers both output polarities.	
ScanStepDuration	10	Time to wait for the next scan step	
ScanFrequency	100	Scan frequency	
ScanStopValue	0	Output value of the scan generator when the scan is off. This parameter can be used for a manual scan.	
ScanStepSize	100	Scan step size	
TEActiveA, B	0	Enables/disables the scan of output voltage A, B	
TEGainA, B	0	Conversion factor from scan generator output to output A, B voltage	
TEOffsetA, B	0	Output A, B voltages at ScanOffset = 0 (added to RegOutA, B and RegResetValueA, B, resp.)	
QIActive	1	Set to 1 to apply the scan settings to the phase set point.	
QIGain	1000000	Conversion factor from scan generator to phase set point.	
QIOffset	0	Phase set point at ScanOffset = 0	

9.8 Output settings

Parameter name	**Default value**	**Description**	**Access mode**

9.9 "Search for signal" settings

Parameter name	**Default value**	**Description**	**Access mode**
Searching	0	Flag indicating that the output is scanned in order to obtain a valid input signal (radius OK and frequency OK)	Read-only

RegSearchSpeedA, B	0	Search speed of regulator A, B. (Regulator starts a search scan if RegSearchSpeed¿0 and RF power is low (radius¡minRadius)	

9.10 Step response settings

Parameter name	Default value	Description	Access mode
SPStepWidth	10000	Amplitude of square signal (for step response measurement)	
SPStepDuration	419430	Period of square signal (for step response measurement), read only	
SPStepRate	16	Sets frequency of square signal (for step response measurement) as fraction of the regulator sampling rate	
CoupleStep	0	Set to 1 to apply square signal to regulator input (serves to measure the step response of the servo loop).	

9.11 Trigger settings

Parameter name	Default value	Description	Access mode
PointTriggerMode	0	Defines event upon which a new scan step is made.	
PointTriggerEdge	0	Sign of optional point trigger TTL input.	
ScanTriggerMode	0	Defines event upon which a new scan is started.	
ScanTriggerEdge	0	Sign/behavior of optional scan trigger TTL input.	
ScanFromMemory	0	Set to 1 in order to generate the scan from values previously written into the FPGA RAM. To be used for arbitrary waveform scans only	
SelectTTLout1	0	Selects the use of the Trigger output BNC connector.	
InvertTTLout1	0	Sets polarity of the Trigger output BNC connector.	

9.12 Motor driver settings

Parameter name	Default value	Description	Access mode

MEnable	0	Enables the motor control.	
MReady	0	Flag indicating that the stepping motor has reached the target position	
MRangeClip	0	Flag indicating that the stepping motor has reached the limit of its range	
MPosition	0	Actual motor position	Read-only
MRegOnOff	0	Switch Motor regulator on / off.	
MRegSign	0	Motor regulator sign.	
MSearchSign	0	Direction of search when using the motor.	
MInputSelect	0	Selection of the input signal for the motor control regulator.	
MWaitForLock	0	Determines whether the motor regulator remains on hold as long as regulator A and B are not locked.	
MSpeedMax	512	Speed limit for motor.	
MSpeedMin	1	Minimum speed for motor.	
MAccel	1	Acceleration limit for motor.	
MCurrentDrive	50000	Drive current of motor.	
MCurrentSndBy	5000	Rest current of motor.	
MRegErrorThres	20000	Minimum error signal level for the motor regulator to react on.	
MSearchSpeed	0	Motor speed during search.	
MRegPGain	0	Motor regulator P gain.	
MRegIGain	0	Motor regulator I gain.	
MPosMax	1073741823	Motor range (maximum)	
MPosMin	-1073741823	Motor range (minimum)	
MOffset	0	Motor position at ScanOffset=0	

9.13 Dither lock settings

Parameter name	**Default value**	**Description**	**Access mode**
ScanModAmplitude	0	Amplitude of sinusoidal modulation on scan generator (for dither lock, e.g.)	
LockInFrequencyA	20000	Dither frequency of dither generator A	
LockInInputSelectA	0	Signal selected a input to demodulation for dither lock.	

LockInHarmonicA	0	Order of derivative generated by demodulation for dither lock (0: direct lock, 1: first derivative demodulation with 1 x f, 2: demodulation with 2f, 3: demodulation with 3f)	
LockInPhaseA	0	Demodulation phase (relative to dither generator)	
LockInLPGainA	1000	Gain of demodulation low pass filter.	
LockInLPFreqA	1000	Cut-off frequency of demodulation low pass filter.	
LockInRegEnableA	0	Setting this value to 1 acitvates the dither lock.	
LockInRegSetPointA	0	Setpoint for dither lock.	
LockInRegSignA	0	Sign of dither lock.	
LockInRegPGainA	0	P gain of dither lock	
LockInRegIGainA	0	I gain of dither lock	
LockInRegDGainA	0	D gain of dither lock	
LockInRegOutSelA	0	Output signal to which the dither lock output is added	
LockInRegOutRangeA	10000	Voltage range that the dither lock output can address.	
LockInDitherAmplA	0	Dither generator output amplitude	
LockInDitherPhaseA	0	Dither generator output phase	
LockInRegLocked	0		
LockInRegHold	0		
LockInRegOutClip	0		

9.14 Measurement settings

Parameter name	**Default value**	**Description**	**Access mode**
MeasClockDivision	0	Used to slow down the reading of measurement values during a scan.	
DatasetNumber	0	Number of measurement being performed.	
NumberOfFrames	0	Number of data frames recorded at each scan point.	
NumberOfPoints	0	Number of measurement points (typically = ScanNmbOfSteps)	
DataSendDelay	100	Time to wait between data packages during transmission to PC	
DataFormat	0	Format used for data transmission to PC	

DataReady	0	=1 if data is available to PC	Read-only
MeasSingleCont	2	Single or continuous measurement.	
MeasAddrOffset	0	Determines memory layout for measurement data.	
MeasChannel1...8	0	Selection of signal to record during a measurement.	
MeasOffset1...8	0	Offset added to measured value before scaling.	
MeasShift1...8	-8	Bit shift applied to measured value before storing to memory.	
MeasMask1...8	255	Bit assignment for storage of measurement value.	
MeasAvrg1...8	0	Number of averages applied to each data point.	

9.15 System information

Parameter name	**Default value**	**Description**	**Access mode**
SerialNumber	9999999		Read-only
Build	1257	Firmware build number	Read-only
Mute	0	Set to 1 to suppress echos and spontaneous outputs to the PC.	
FPGAFirmware	0	FPGA firmware version	Read-only
LCDBrightness	100	LCD brightness	
ScreenSaverEnable	1	Set to 1 to enable white screen.	
ScreenSaverDelay	120	Time in minutes after which the TFT screen turns white.	

10 Electrical Specifications

10.1 Technical Data

Sensor head	
Wavelength ranges (free beam input)	380. . . 1100 nm 800. . . 1700 nm (IR option) 800. . . 1700 nm (IRext option)
Input aperture	2 mm
Wavelength ranges (fiber-coupled input)	360. . . 410 nm (nufern PM-S350-HP) 470. . . 620 nm (nufern PM-S405-HP) 500. . . 700 nm (nufern PM460-HP) 620. . . 850 nm (nufern PM630-HP) 770. . . 1100 nm (nufern PM780-HP) 970. . . 1500 nm (nufern PM980-XP) 1270. . . 1625 nm (nufern PM1300B-XP) 1850. . . 2000 nm (nufern PM1950)
Free spectral range	8 GHz (standard) others on demand
required optical input power	0.1. . . 1 mW
Bandwidth	1 MHz ... 1 GHz (standard configuration)
Sampling rate	1.25 MSps
Outputs	
Voltage range LV (front)	-10.0...10.0 V at 1 kΩ load
Bandwidth LV	200 kHz
Voltage range HV (rear)	0...150 V 120mA continuous, 240mA peak (each channel)
Bandwidth HV	100 kHz (small signal bandwidth)
Sampling rate	1.25 MSps
Interfaces	
	USB on demand: RS-232 Ethernet
Supply	
Voltage range	100...240 V AC, 50...60 Hz
Voltage range (DC12V option only)	DC 9...36V; 5.5x2.5mm plug; positive polarity
Power consumption	Typ. ≈ 10 W, 20 W with HV option, max. 50 W at full load
Housing (desktop case)	
Dimensions	3 (height, width, length)
Size	100mm x 260mm x 377mm
Housing (19 inch rack case)	
Size	150mm x 450mm x 340mm
Display	
Size	4.3 inch (11 cm) TFT display
Resolution	480 x 272, 16-bit color

Technology	resistive touchscreen, LED backlight

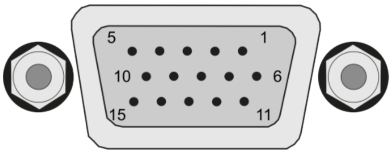
10.2 Mains Power Cable

Use the included power supply cable that provides proper grounding contact. The system may be delivered with country-specific mains power cables.

The power supply automatically adapts to local main power supplies of 100...120 VAC, 220...240 VAC.

10.3 HD-15 Connector

NOTICE: Only use the cable delivered with your system. Using standard cables like those that are used for personal computers can lead to malfunction or damage of electronic components. Many available cables have internal connections (common shielding of R, G, B) or some pins are not connected.



1	input X
2	input Y
3	input intensity
4	auxiliary input
5	analog ground
6	$+15$V
7	-15V
8	system ground
9	I^2C clock
10	I^2C and SPI data
11	TEC $-$
12	TEC $+$
13	Temperature control signal
14	Base plate temperature signal
15	SPI clock

11 Delivery Content

(see section 3)

12 Customer Service

In case of service needs, general questions, need of repair or warranty claims you will get quick and effective support at:

TEM Messtechnik GmbH
Grosser Hillen 38
D-30559 Hannover
Germany

Tel: +49 (0)511 51 08 96 -30
Fax: +49 (0)511 51 08 96 -38

E-mail: `mailto:info@TEM-messtechnik.de`
URL: `http://www.TEM-Messtechnik.de`

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