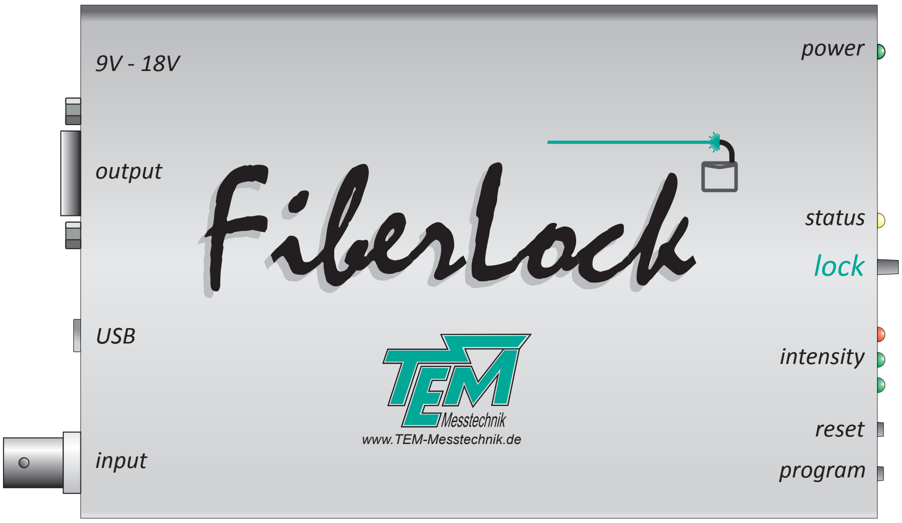
FiberLock Manual

TEM Messtechnik GmbH

July 26, 2021



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Contents

1 Delivery Content

Your *FiberLock* system consists of the following components:

- *FiberLock* electronics: contains a pre-amplifier for the photo diode input, a microcontroller for digital signal processing and communication with a PC and output amplifiers to drive the piezo-based actuator
- Piezo-actuator mirror: the standard actuator is a piezo-driven mirror which tilts in x- and y-directions
- Power adapter
- HD-15 extension cable
- Software installation CD

Please check the contents of your delivery for completeness.

2 Basic Operation

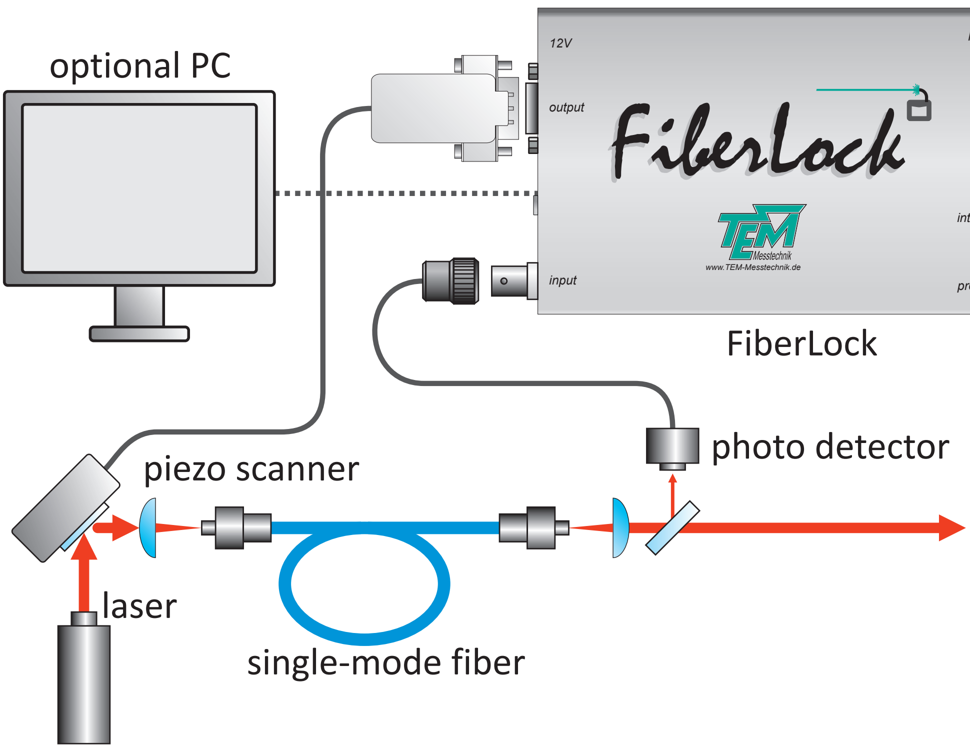
Single mode fiber coupling is often time consuming, because very high mechanical precision in the sub-micrometer range is necessary. Expensive translating and tilting devices with good long-term stability must be used. In order to optimize the amount of light coupled into the fiber, various components of the setup may be moved alternatively:

- the laser beam by redirecting mirrors on piezo actors
- the coupling optics (e.g. a small aspherical lens)
- the fiber end itself (e.g. for open fibers without attached fiber connectors)

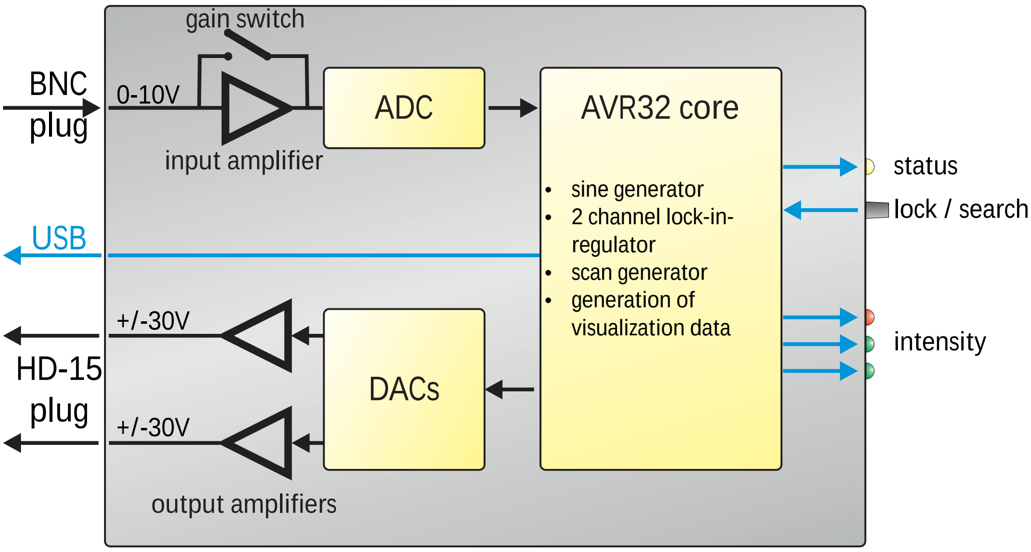
The *FiberLock* simplifies this process in two ways: Firstly, it can scan the laser in x- and y-directions. This makes finding the fiber aperture much easier and the live display capabilities allow the convenient optimization of other degrees of freedom, such as the focus. Secondly, as the name suggests, the *FiberLock* can lock the laser beam onto the fiber aperture and efficiently compensate for drifts and vibrations in the optical setup, eliminating the need for manual re-adjustment.

2.1 Principles

The *FiberLock* connects to an optical assembly via two connectors. The input connector (BNC plug) is connected to a photo diode signal, which detects the intensity of light coupled into the optical fiber. The output connector (HD-15 socket) controls the position of the piezo-mirror. This should be placed just in front of the collimating lens. This way, tilting the piezo-mirror leads to position changes of the beam focus.



Optionally, the *FiberLock* can be connected to a PC via USB. On the one hand, this facilitates to parameterize and customize the electronics. On the other hand, the scanning functionality can visualize the fiber coupling and help to optimize other degrees of freedom, such as the beam angle or the focus. Internally, the *FiberLock* features an input amplifier with electronically adjustable wide-range gain. The gain-adjusted analog input signal passes an analog-to-digital converter before entering the micro-controller core, which takes care of all signal processing. In locking mode, this controller adjusts the x- and y- angles of the actuator mirror with two lock-in regulators, generating the necessary modulation signals. In scanning mode, the measured photo diode signal is processed and sent to the PC for visualization. Any output to the actuator is converted to analog voltages with digital-to-analog converters and subsequently amplified by fast op-amps to the working range of the piezo actuator.



2.2 Recommended Hardware Setup

To get the full benefit from working with the *FiberLock*, a few guidelines concerning the hardware setup should be followed. Firstly, the piezo actuator should be attached to an adjustable mirror mount to allow for manual compensations of the mirror angle if the actuator working range is exceeded. Please place the actuator as close to the collimating lens a possible Secondly, another adjustable mirror should be present in the beam path in order to change the beam position on the collimating lens. Lastly, the focussing lens and an optional mode-matching lens should be easily movable along the optical axis, so that their positions can be optimized "live", while the *FiberLock* is active. These hints are shown schematically in Fig. 1.

2.3 Scanning

To facilitate and visualize the initial coupling into the fiber, it is possible to scan the fiber aperture using the full range of the piezo actuator. During this raster scan, the laser intensities at the fiber output are recorded and can be viewed as a 3-D plot. To this end, it is necessary to connect a PC to the *FiberLock* electronics and start the *Kangoo* software. In fact, the scanning functionality is only available in combination with a connected PC.

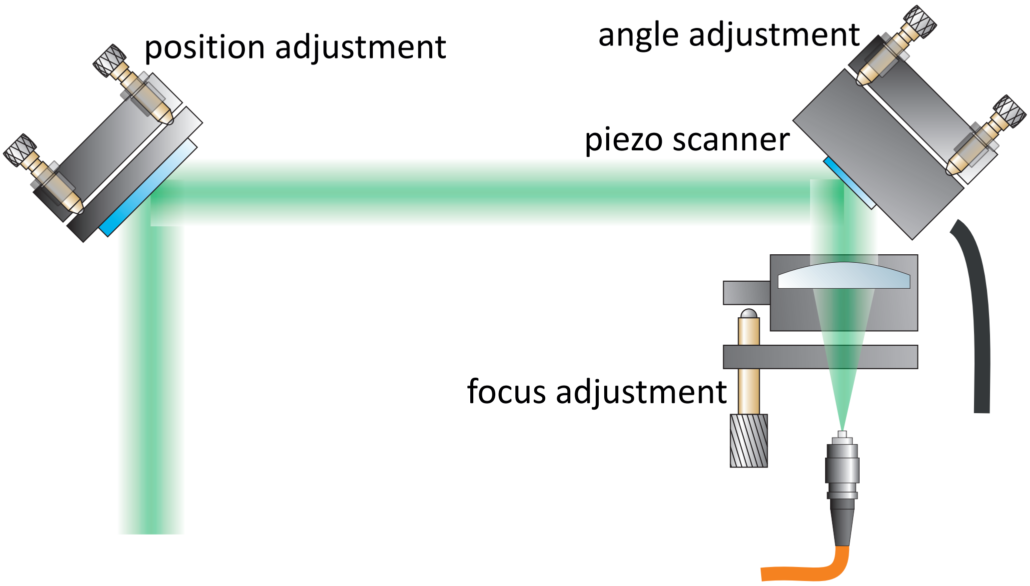


Figure 1: Recommended hardware setup for a *FiberLock* system.

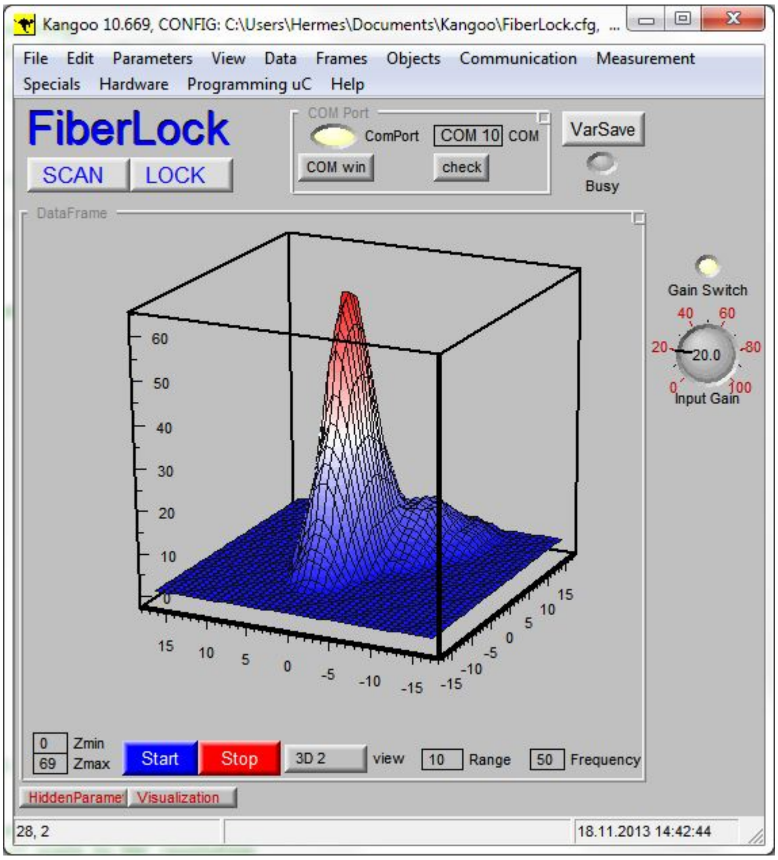


Figure 2: Software interface for scans.

Figure 2 shows the software interface for the scanning functionality. The scan is started or stopped using the blue and red "START" and "STOP" buttons at the bottom of the frame. The drop-down list to the right of these buttons changes the view angle of the 3D plot. In addition, the scan frequency and scan range can be changed. To the right of the frame, the gain of the input amplifier can be adjusted. The LED-button "Gain switch" turn the input amplifier into a transimpedance amplifier for the case that a photo diode is directly connected to the *FiberLock* electronics.

Once a peak has been found during scanning, the 3D display can further be used to optimize this peak and move it to the center of the actuator's working range.

2.4 Locking

In the Kangoo software, please change to the locking view using the "LOCK" button at the top of the interface. This shows a 2D-display of the current actuator position, an intensity indicator and a recorder to track intensity changes (c. f. Fig. 3). Start the lock by pressing the "Lock"-LED in the software interface or by pressing the *FiberLock*'s front panel key. This will start the lock-in regulator, which adds a small circular modulation to the actuator position. If the actuator is not aligned to achieve optimal fiber coupling, this modulation will show in the output intensity. This allows the lock-in regulator to correct the actuator position and stabilize it to maximize the fiber coupling efficiency.

To achieve good results, please adjust the input gain such that the intensity is at about fifty

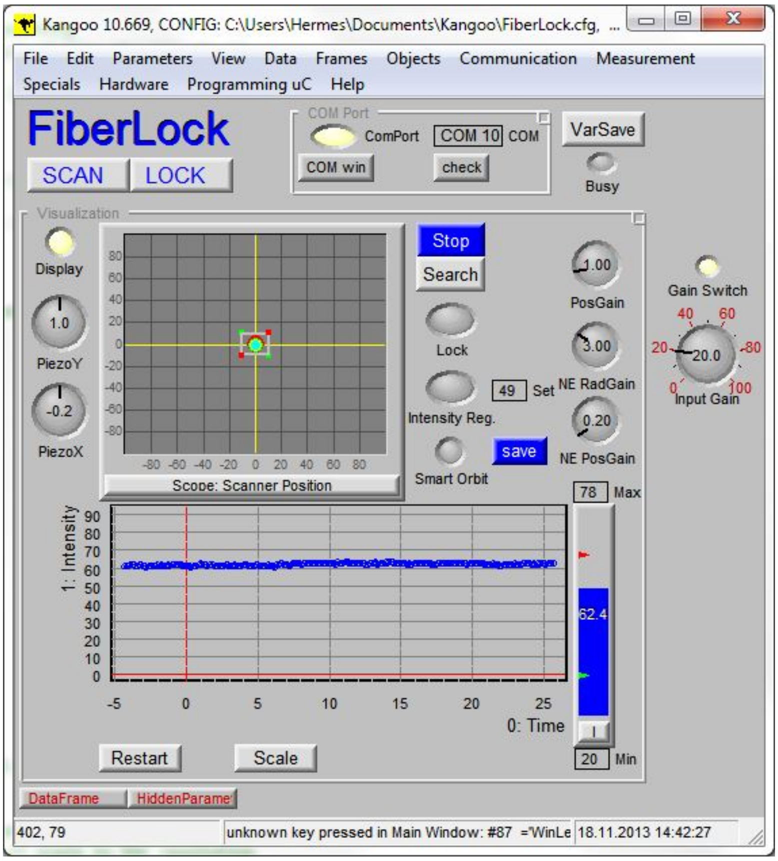


Figure 3: Software interface for locking with intensity recorder.

percent. Using the "PosGain" dial, the gain of the position regulator can be adjusted. A very low gain value will make it difficult for the regulator to follow during manual adjustments to the system, while excessively large gain values lead to oscillations which will show in the measured intensities.

2.4.1 Optimization of all Parameters

Fiber coupling depends on a number of alignment parameters, for example the angle at which the laser enters the fiber, the position of the fiber aperture and the focus position along the axis of the fiber. In a typical optical setup, these parameters are not independent of each other: Changing the focus can hardly be done without affecting the position of the fiber aperture, a change of the horizontal beam angle typically also affects the vertical angle, etc. This makes the manual optimization of all involved degrees of freedom very difficult and time-consuming.
Although the *FiberLock* only locks two degrees of freedom (say the horizontal and vertical beam position), this greatly simplifies the manual optimization of the remaining parameters. The focus position, for example, can now be changed without worrying about affecting the beam position, since this will be automatically adjusted by the *FiberLock*. If the gain of the position regulator is well adjusted, all other degrees of freedom of the fiber coupling can be manually adjusted in a fast and simple manner without ever losing the lock.

2.5 Search Function

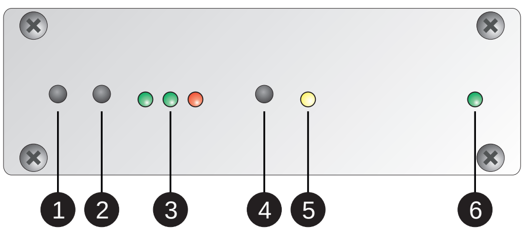
The search function can be triggered from within the software or by pressing and holding the button on the front panel. The *FiberLock* will start to scan over the fiber aperture and automatically lock on to the found intensity peak. This functionality is very useful when the coupling has been lost, for example by manual misalignment of the optical elements. As long as the misalignment is small (within the scan range of the actuator), the search function will re-lock within seconds.

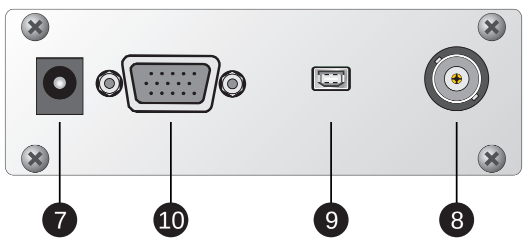
2.6 Saving Settings

Any parameter changes are lost as soon as the *FiberLock* loses power or resets. In order to make changes permanent, the dialed settings must be committed to the microcontroller's non-volatile memory. This is achieved with the "VarSave" button in the *Kangoo* interface. To change saved settings, simply overwrite them by changing some parameters and pressing "VarSave" again. At the next system start, these saved settings will be loaded and used as default parameter. An exception to this is the started of the regulator, which is always off at start-up.

2.7 Operation Without PC

While it is useful to connect the *FiberLock* to a PC for visualization and for setting parameters, the device can work on its own and is indeed intended to do so for every-day operation. The following description of the front and real panel elements shows how to operate the *FiberLock* without a PC.





1	Program button. Used for firmware upgrades only.
2	Reset button. Resets the *FiberLock* electronics; equivalent to disconnecting and reconnecting the power supply.
3	Intensity indicators. These show the currently measured photo diode intensity, with software-adjustable thresholds.
4	Push button. Press short to start/stop the locking. Press and hold to start a search.
5	Status LED. Slow breathing: idle; fast breathing: locking; very fast breathing: searching; continuously on: scanning.
6	Power LED. Lights up as soon as the device is powered.
7	Power connector. Takes DC input voltages, 9 to 18V. 2.5mm pin. GND on ring.
8	BNC connector. For connecting a photo diode signal. Input range: 0...10V.
9	USB connection.
10	HD-15 connector. Provides the driving signals for the piezo actuator.

A typical situation is the following: The *FiberLock* is switched on, but the optical setup has drifted and the optimal actuator position has changed. This will be indicated by the three front-panel LEDs, which act as a simple but efficient intensity indicator. If at least some intensity still couples into the fiber, press the key to activate the locking function, and the *FiberLock* should immediately lock to maximum intensity. If the fiber coupling has drifted too far and no light is coupled into the fiber, press and hold the key until the search function starts. The *FiberLock* will search for the position of the fiber and then automatically switch into lock.

3 Advanced Operation

3.1 Intensity Thresholds

In order to show whether the lock is intact or whether the fiber-coupling drifts when locking is off, the *FiberLock* has a simple intensity indicator in the form of three LEDs in the front panel. If the intensity is too high, the red LED lights up. If the intensity is too low, only the left green LED will light up. The corresponding intensity thresholds can be changed in the software interface.

CAUTION: The lower intensity bound has a second function: During a search scan, the search will terminate as soon as an intensity value above this lower threshold is detected. Therefore, setting the threshold too low or excessively high may interfere with the search functionality.

3.2 Modulation Amplitude

When locking, the mirror angles are modulated by the lock-in regulator. For a one-dimensional system, this would lead to intensity fluctuations in the fiber output light. The *FiberLock*, however, locks in two dimensions, which opens a way to circumvent this problem. The sinusoidal modulations of the x-Axis and the y-Axis are phase shifted by 90 degrees, leading to an effective circular motion of the beam focus on the fiber aperture. For a well-focused, round laser beam, this means that the intensity coupled into the fiber is constant (the focus is moving on a constant level curve of the intensity distribution). By changing the size of the modulation circle, we can effectively control the amount of light coupled into the fiber. For most applications, this intensity should be maximized, corresponding to a small circle size. A larger circle size on the other hand will lead to a more robust lock and may make sense in noisy setups.

3.3 Noise-Eater Mode

The *FiberLock* can, in addition to locking to the maximum coupling intensity, work in "Noise-Eater Mode". In this mode, the quality of the fiber coupling is constantly adjusted in order to achieve a constant intensity at the fiber output. This "Noise-Eater Mode" is enabled by the "Intensity Reg." button. The actuator now modulates much more slowly and constantly adjusts the modulation radius in a attempt to keep the output intensity at a constant level. As a side-effect, this will deform the orbit shape whenever the laser's beam profile is not circular. For elliptical beam profiles for instance, this mode can be used to force an elliptical modulation orbit of the actuator. Using the blue "Save" button, this orbit can be saved and then switched on or off using the "Smart Orbit" LED button. Once learnt, the smart orbit functionality also works when the regulator is not in "Noise-Eater Mode" and can greatly reduce the residual intensity fluctuations introduced by the actuator's modulation.

3.4 Chopped Lasers

The *FiberLock* works for with chopped lasers up to a chopping frequency of about $1kHz$. The electronics automatically detect whether the intensity input signal is chopped and reacts accordingly. Therefore, no additional parameterization is necessary. The only adjustable parameter is "ChopperOffThreshold", found in the section "Hidden Parameters". Here, one can enter the threshold

(in percent of the maximum intensity) below which the laser is considered *off*, or blocked by the chopper.
Even the Noise-Eater mode works with chopped lasers, but the regulator gain may have to be optimized to achieve a good performance.

3.5 Scaled Output Signals

Please note that the two output signals of the *FiberLock* are not equally scaled. The output in x-direction is reduced by a factor of $\sqrt{2}$ to compensate for the fact that mirror tilts in the x-direction deflect the laser stronger than tilts in the y-direction. This is important for the orientation of the piezo-actuator: It's x-axis should be aligned to the plane spanned by the incident and the refected beam (typically the plane of the optical table). By the variable FL_Scale this scaling can be switched on/off.

3.6 List of Variables and Commands

3.6.1 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
$\langle variablename\rangle$= $\langle value\rangle\langle CR\rangle$

3.6.2 Variable Table

The following table lists *FiberLock* variables. At the terminal, these can be listed by entering the command "VarDump".

Variable	**Default**	**Min**	**Max**	**Comment**

SerialNumber	-	-	-	serial number of the device
Build	283	0	99999	encodes the firmware version
FL_PosX, -Y	0	-2048	2047	x- and y- positions of the piezo actuator
FL_MinRadius	50	1	4095	minimum modulation radius
FL_TransImp	0	0	1	transimpedance switch for the input amplifier
FL_PosGain	100	0	65536	gain for the position regulator
FL_RadGain	3000	0	65536	intensity regulator gain in NoiseEater mode
FL_RadPosGain	20	0	65535	position regulator gain in NoiseEater mode
FL_PdGain	500	0	1000	gain of the input amplifier
FL_IntReg	0	0	1	enables the NoiseEater mode
FL_Volts	0	2000	-	raw signal from ADC in mV
FL_Scale	1	0	1	Scaling of the x-Piezo by factor 1.41
ScamM_Mode	0	0	1	0: off, 1: scan, 2: search, 3: lock
ScanM_StepsX	41	2	50	number of rows and columns for a scan
ScanM_FreqX	250	1	10000	scan frequency, arbitrary units
ScanM_Range	1000	1	2047	scan range
FL_IntLow	400	1	2000	lower intensity threshold
FL_IntHigh	1600	100	2047	upper intensity threshold
FL_IntSet	1000	100	2047	set point for the NoiseEater mode
FcutOff	10000	200	200000	cut-off frequency of the input low-pass filter [Hz]
FL_Orbit	0	0	1	enables the smart orbit
FL_AutoRelock	0	0	1	enables the automatic re-lock search
FL_RelockPeriod	3000	10	60000	time before re-lock search [ms]
FL_RelockThreshold	50	0	100	re-lock threshold (in % of min. intensity)
FL_ChopThreshold	5	-10	100	laser-off threshold for chopped lasers
FL_IsrFreq	12800	0	21300	loop speed of the regulator

3.6.3 Command Table

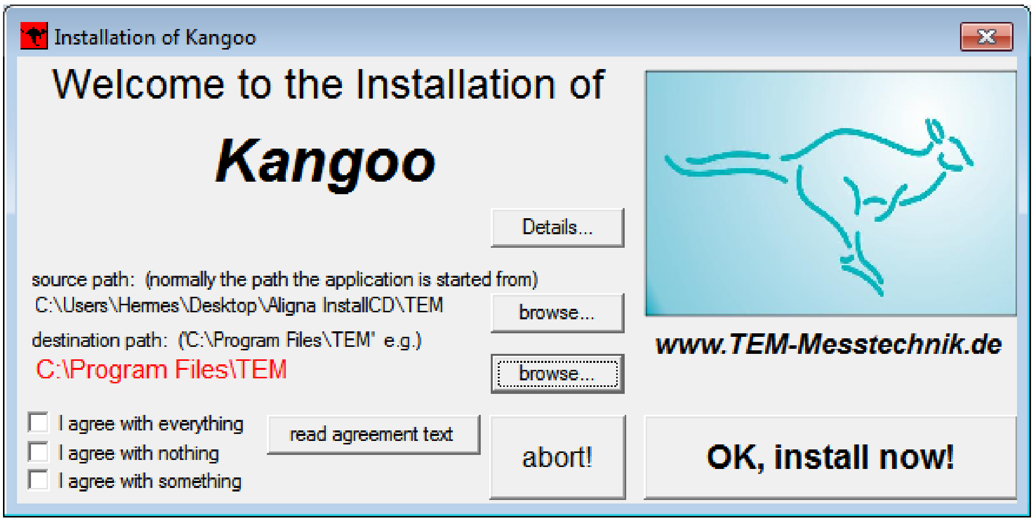
The following table lists *FiberLock* commands. At the terminal, these can be listed by entering the command "CmdDump".

Command	**Arg. 1**	**Arg. 1**	**Comment**
Reset	-	-	resets the micro-controller
Stop	-	-	stops scans, searches or locking
FL_PrntVars	-	-	prints the current intensity and actuator positions
SaveOrbit	-	-	saves the current orbit as smart orbit
FL_VarSave	-	-	saves settings to EEPROM (equivalent to "VarSave")

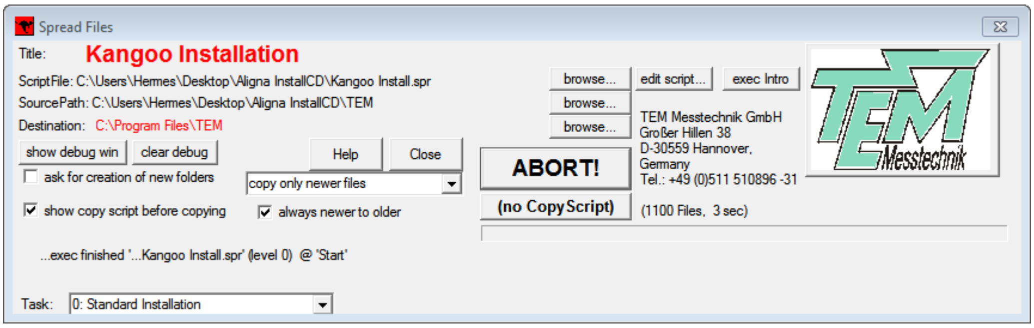
4 Software Installation

4.1 Installation of the Kangoo Software

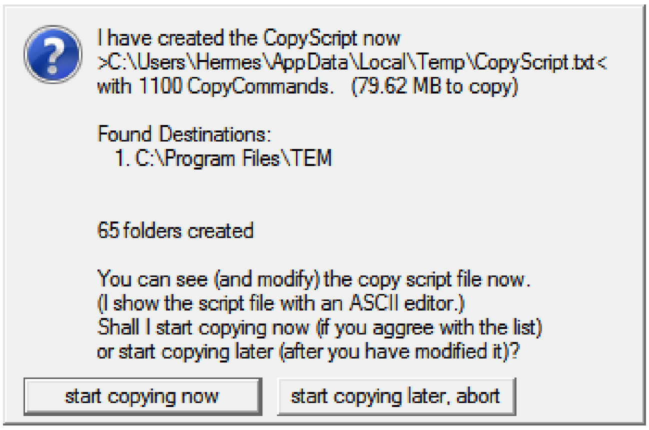
To install the Kangoo software, start the program Install.exe in the root directory of the installation CD or USB memory stick, resp.. The installer will show a welcome screen with several options.

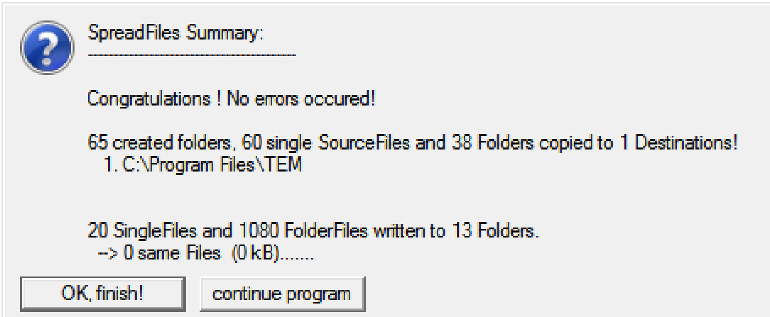


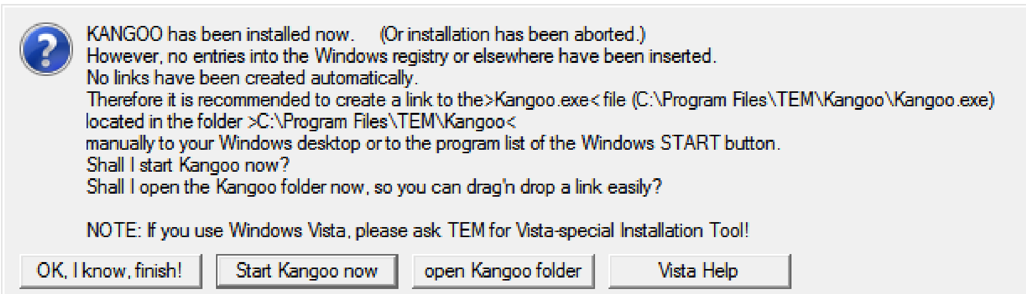
The default options should work fine, with the possible exception of the section "Destination Path", where the destination directory is specified. The standard directory is "TEM" in the "Program Files" folder. On Windows Visa or Windows 7 systems, please avoid the "Program Files" folder and choose and 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.







4.2 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.

4.3 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 4).

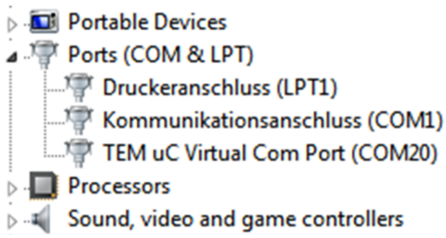


Figure 4: TEM COM Port in the device manager

4.4 Upgrading the Firmware

Please contact TEM Messtechnik for details about firmware upgrades.

5 Connectors and Electrical Specifications

5.1 Mains Power Cable

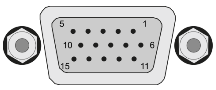
Please use the included power supply. When using a different power adapter, ensure that it provides a direct voltage in the range 9V to 18V and at least 1.5A of current.

5.2 BNC Connector

The BNC connector is the input for the photo intensity signal at the fiber output. It can serve as both current and voltage input, with a software switch to select either mode. If an external pre-amplifier is used, use an input signal between zero and ten volts.

5.3 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.



Hd15 Socket

1	
2	
3	
4	
5	
6	+15V
7	-15V
8	GND
9	
10	-HV (-30V or -60V)
11	Output A
12	Output B
13	
14	
15	+HV (+30V or +60V)

6 Safety Instructions

Before operating the *FiberLock*, 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 *FiberLock* device is intended for laboratory use only. The *FiberLock* device should be operated by trained personnel.

CAUTION! The *FiberLock* 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 *FiberLock* is intended for indoor operation with a temperature range of $+5°C$ to $+45°C$. Do not subject to heat, direct sunlight or the influence of other electric devices. Protect from humidity, dust, aggressive liquids and vapors.

CAUTION! The *FiberLock* 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 *FiberLock* to third parties only with this manual.

7 Customer Service

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

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E-mail: `mailto:info@TEM-messtechnik.de`
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Notes