

KNA-IR and KNA-VIS K-Cube NanoTrak[®] Auto-Alignment Controller

APT User Guide



Original Instructions

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Chapter 1 Overview

1.1 Introduction

The NanoTrak[®] Controller represents the latest developments in automated optical alignment technology. Its space-saving design combines an active-feedback optical alignment system and a two-channel piezoelectric controller in a single unit, allowing the user to align optical fibers and optimize the coupling of light into and out of photonic devices. Operator interaction is via the top panel menu or an intuitive software interface. It is available in two wavelength ranges, 900 - 1700 nm (KNA-IR) and 320 - 1000 nm (KNA-VIS).

The controller is supplied with a full suite of software support tools. An intuitive graphical instrument panel allows immediate control and visualization of the operation of the NanoTrak controller, and any other controllers that are installed in the system. See Section 1.3. for a full description of the software.

The unit operation is fully configurable (parameterized); key settings are adjustable through the graphical interface panel. Track or Latch operating modes can be selected 'on the fly', and in both modes the display can be changed to show drive voltage or position (in microns). In the FEEDBACK (closed loop) operation mode, both the P & I (proportional and integral) components of the feedback control loop can be altered to adjust the servo loop response. For convenience and ease of use, adjustment of many key parameters is possible through direct interaction with the graphical panel. For example, the output drive voltage or position can be adjusted by rotating a "software-panel" control knob (see the tutorial in Chapter 4 for further details). Note that all such settings and parameters are also accessible through the programmable interfaces which allow the user to build automated alignment routines. See Section 1.3. for a full description of the APT software.

The key innovation of the Thorlabs range of controllers and associated mechanical products is the ease and speed with which complete automated alignment systems can be engineered at both the hardware and software level. All controllers in the range are equipped with USB connectivity. The 'multi-drop' USB bus allows multiple units to be connected to a single controller PC using commercial USB hubs and cables. When planning an alignment application, simply add up the number and type of drive channels required and connect together the associated number of controllers.

1.2 Power Options

A compact power supply unit (TPS002) is available from Thorlabs. This power supply unit is designed to take up minimal space and can be mounted to the optical table in close proximity to the driver units, connected via short power leads. Although the TPS002 has two outputs, it should not be used to drive another K-Cube as well as the KNA unit. Doing so could exceed its current limits.

As a further level of convenience when using these controllers, Thorlabs also offers the new K-Cube Controller Hubs (KCH301 and KCH601). These products have been designed specifically with multiple K-Cube operation in mind in order to simplify issues such as cable management, power supply routing and different optical table mounting scenarios. The KCH301 hub provides power distribution for up to three K-Cubes, while the KCH601 hub provides power distribution for up to six K-Cubes. Either hub requires only a single power connection.

The Controller Hub comprises a slim base-plate type carrier with electrical connections located on the upper surface: the KCH301 measures 193.5 mm x 70.0 mm x 24.0 mm (7.62" x 2.76" x 0.94") and accepts up to three K-Cubes while the KCH601 measures 376.5 mm x 70.0 mm x 24.0 mm (14.82" x 2.76" x 0.94") and accepts up to six K-Cubes.

Note

A KCH series hub can only be used to provide power and USB connection to the host PC. A hub cannot be used to communicate between a KNA-IR or KNA-VIS unit and other K-Cubes also fitted to the hub.

1.3 PC Software Overview

1.3.1 Introduction

As a member of the APT range of controllers, the KNA NanoTrak K-Cube shares many of the associated software benefits. This includes USB connectivity (allowing multiple units to be used together on a single PC), fully featured Graphical User Interface (GUI) panels, and extensive software function libraries for custom application development.

The APT software suite supplied with all APT controllers provides a flexible and powerful PC based control system both for users of the equipment, and software programmers aiming to automate its operation.

For users, the APTUser (see Section 1.3.2.) and APTConfig (see Section 1.3.3.) utilities allow full control of all settings and operating modes enabling complete 'out-of-box' operation without the need to develop any further custom software. Both utilities are built on top of a sophisticated, multi-threaded ActiveX 'engine' (called the APT server) which provides all of the necessary APT system software services such as generation of GUI panels, communications handling for multiple USB units, and logging of all system activity to assist in hardware trouble shooting. It is this APT server 'engine' that is used by software developers to allow the creation of advanced automated positioning applications very rapidly and with great ease. The APT server is described in more detail in Section 1.3.4.

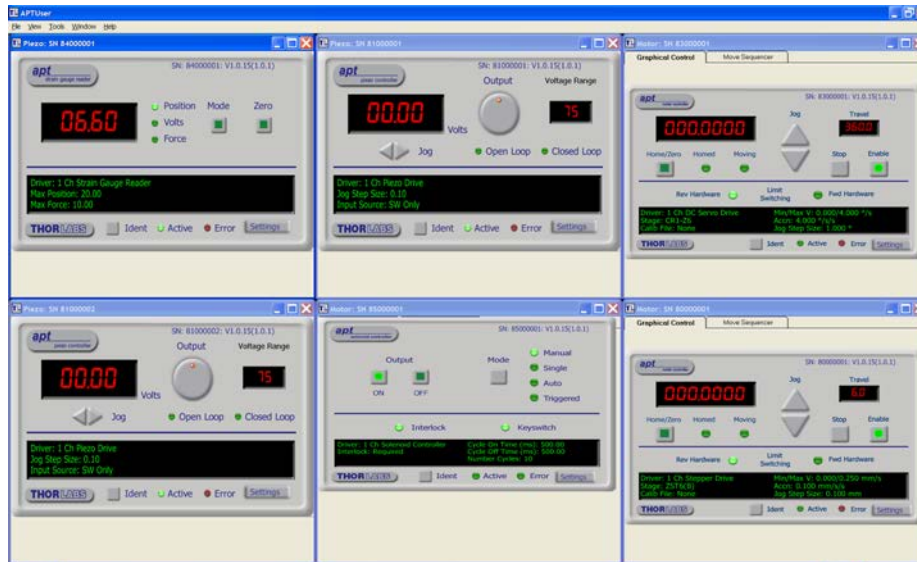
Aside

ActiveX®, a Windows®-based, language-independent technology, allows a user to quickly develop custom applications that automate the control of APT system hardware units. Development environments supported by ActiveX® technology include Visual Basic®, LabView™, Borland C++ Builder, Visual C++, Delphi™, and many others. ActiveX® technology is also supported by .NET development environments such as Visual Basic.NET and Visual C#.NET.

ActiveX controls are a specific form of ActiveX technology that provide both a user interface and a programming interface. An ActiveX control is supplied for each type of APT hardware unit to provide specific controller functionality to the software developer. See Section 1.3.4. for further details.

1.3.2 APTUser Utility

The APTUser application allows the user to interact with a number of APT hardware control units connected to the host PC. This program displays multiple graphical instrument panels to allow multiple APT units to be controlled simultaneously.



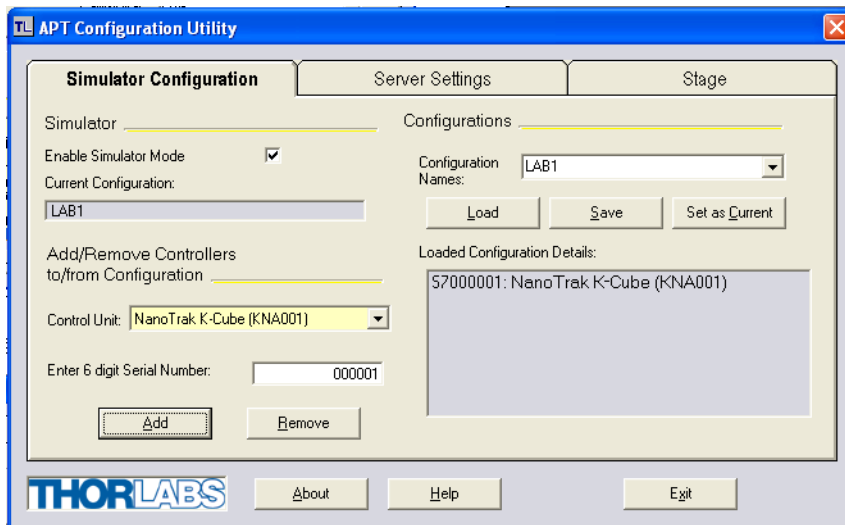
All basic operating parameters can be altered and, similarly, all operations (such as setting the scan circle size) can be initiated. Settings and parameter changes can be saved and loaded to allow multiple operating configurations to be created and easily applied.

For many users, the APTUser application provides all of the functionality necessary to operate the APT hardware without the need to develop any further custom software. For those who do need to further customize and automate usage of the controller (e.g. to implement a positioning algorithm), this application illustrates how the rich functionality provided by the APT ActiveX server is exposed by a client application.

Use of the APT User utility is covered in the PC tutorial (Chapter 5) and in the APTUser online help file, accessed via the F1 key when using the APTUser utility.

1.3.3 APT Config Utility

There are many system parameters and configuration settings associated with the operation of the APT Server. Most can be directly accessed using the various graphical panels, however there are several system wide settings that can only be made 'off-line' before running the APT software. These settings have global effect; such as switching between simulator and real operating mode and incorporation of calibration data.



The APTConfig utility is provided as a convenient means for making these system wide settings and adjustments. Full details on using APTConfig are provided in the online help supplied with the utility.

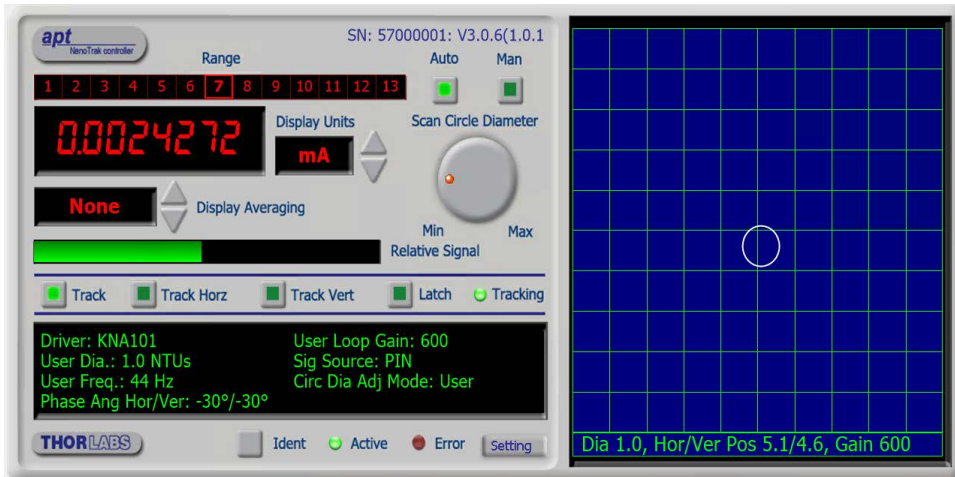
Use of the APT Config utility is covered in the PC tutorial (Chapter 5) and in the APTConfig online help file, accessed via the F1 key when using the APTConfig utility.

1.3.4 APT Server (ActiveX Controls)

ActiveX Controls are re-usable compiled software components that supply both a graphical user interface and a programmable interface. Many such Controls are available for Windows applications development, providing a large range of re-usable functionality. For example, there are Controls available that can be used to manipulate image files, connect to the internet or simply provide user interface components such as buttons and list boxes.

With the APT system, ActiveX Controls are deployed to allow direct control over (and also reflect the status of) the range of electronic controller units, including the KSG101 Strain Gauge controller. Software applications that use ActiveX Controls are often referred to as 'client applications'. Based on ActiveX interfacing technology, an ActiveX Control is a language independent software component. Consequently ActiveX Controls can be incorporated into a wide range of software development environments for use by client application developers. Development environments supported include Visual Basic, Labview, Visual C++, C++ Builder, HPVee, Matlab, VB.NET, C#.NET and, via VBA, Microsoft Office applications such as Excel and Word.

Consider the ActiveX Control supplied for a KNA NanoTrak K-Cube unit.



This Control provides a complete user graphical instrument panel to allow the NanoTrak unit to be manually operated, as well as a complete set of software functions (often called methods) to allow all parameters to be set and NanoTrak control operations to be automated by a client application. The instrument panel reflects the current operating state of the controller unit to which it is associated (e.g. such as Relative Power). Updates to the panel take place automatically when a user (client) application is making software calls into the same Control. For example, if a client application instructs the associated NanoTrak Control to track the position of optimum power, progress is monitored automatically by changing position of the circle on the graphical interface, without the need for further programming intervention.

The APT ActiveX Controls collection provides a rich set of graphical user panels and programmable interfaces allowing users and client application developers to interact seamlessly with the APT hardware. Each of the APT controllers has an associated ActiveX Control and these are described fully in system online help. Note that the APTUser and APTConfig utilities take advantage of and are built on top of the powerful functionality provided by the APT ActiveX Server (as shown in Fig. 1.1).

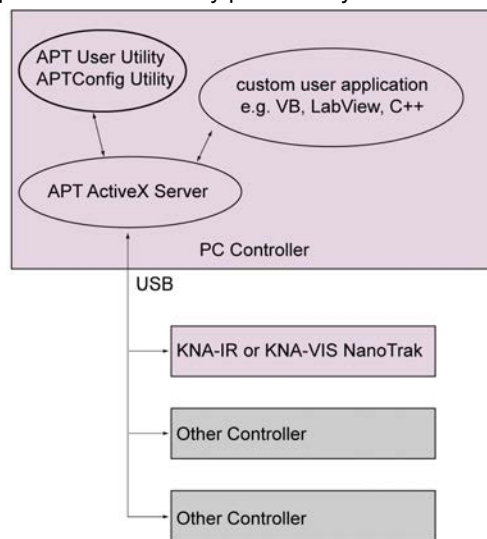


Fig. 1.1 System Architecture Diagram

Refer to the main APT Software online help file, APTServer.hlp, for a complete programmers guide and reference material on using the APT ActiveX Controls collection. Additional software developer support is provided on our website.

1.3.5 Software Upgrades

Thorlabs operate a policy of continuous product development and may issue software upgrades as necessary. The latest software can be downloaded from the 'services' section of www.thorlabs.com.

Chapter 2 Safety

2.1 Safety Information

For the continuing safety of the operators of this equipment, and the protection of the equipment itself, the operator should take note of the **Warnings**, **Cautions**, and **Notes** throughout this handbook and, where visible, on the product itself.

The following safety symbols may be used throughout the handbook and on the equipment itself.



Warning: Risk of Electrical Shock

Given when there is a risk of injury from electrical shock.



Warning

Given when there is a risk of injury to users.



Caution

Given when there is a risk of damage to the product.

Note

Clarification of an instruction or additional information.

2.2 General Warnings



Warning

If this equipment is used in a manner not specified in the handbook, the protection provided by the equipment may be impaired. In particular, excessive moisture may impair operation.

This product generates, uses, and outputs high voltages from the SMC connector (HV Out 1 and HV Out 2) that are hazardous and can cause serious injury. In any installation that uses the NanoTrak it is the user's responsibility to ensure adequate insulation and precautions are taken to avoid shock risk. Cables for HV Out must be rated for 250 V RMS.

Spillage of fluid, such as sample solutions, should be avoided. If spillage does occur, clean up immediately using absorbant tissue. Do not allow spilled fluid to enter the internal mechanism.

The equipment is for indoor use only.



Warning

If your PC becomes unresponsive (e.g due to an operating system problem, entering a sleep state condition, or screen saver operation) for a prolonged period, this will interrupt communication between the APT Software and the hardware, and a communications error may be generated. To minimize the possibility of this happening it is strongly recommended that any such modes that result in prolonged unresponsiveness be disabled before the software is run. Please consult your system administrator or contact Thorlabs technical support for more details.

Chapter 3 Getting Started

3.1 Install The Software

Note

When operating via a PC, direct user interaction with the unit is accomplished through intuitive graphical user interface panels (GUIs), which expose all key operating parameters and modes. The user can select multiple panel views displaying different information about a particular hardware unit. The multitasking architecture ensures that the graphical control panels always remain live, showing all current hardware activity.



Caution

Some PCs may have been configured to restrict the users ability to load software, and on these systems the software may not install/run. If you are in any doubt about your rights to install/run software, please consult your system administrator before attempting to install.

If you experience any problems when installing software, contact Thorlabs on +44 (0)1353 654440 and ask for Technical Support.

DO NOT CONNECT THE CONTROLLER TO YOUR PC YET

- 1) Go to *Services/Software Downloads/Motion Controllers* at www.thorlabs.com and download the *Servo, Stepper and Closed-Loop Piezo Controllers* software.
- 2) Run the .exe file and follow the on-screen instructions.

3.2 Mechanical Installation

3.2.1 Environmental Conditions



Warning

Operation outside the following environmental limits may adversely affect operator safety.

Location	Indoor use only
Maximum altitude	2000 m
Temperature range	5°C to 40°C
Maximum Humidity	Less than 80% RH (non-condensing) at 31°C

To ensure reliable operation the unit should not be exposed to corrosive agents or excessive moisture, heat or dust.

If the unit has been stored at a low temperature or in an environment of high humidity, it must be allowed to reach ambient conditions before being powered up.

The unit must not be used in an explosive environment.

3.2.2 Mounting Options

The K-Cube NanoTrak is shipped with a baseplate, for use when fitting to a breadboard, optical table or similar surface - see Section 3.2.3.

For multiple cube systems, a 3-channel and 6-channel K-Cube Controller Hub (KCH301 and KCH601) are also available - see Section 1.2. for further details. Full instructions on the fitting and use of the controller hub are contained in the handbook available at www.thorlabs.com.



Caution

When siting the unit, it should be positioned such that natural air flow around the unit is not restricted. Do not cover the unit.

When siting the unit, it should be positioned so as not to impede the operation of the control panel buttons.

3.2.3 Using the Baseplate

The baseplate must be bolted to the worksurface before the K-Cube is fitted, as shown below. The K-cube is then located on two dowels in the baseplate and secured by four clips.

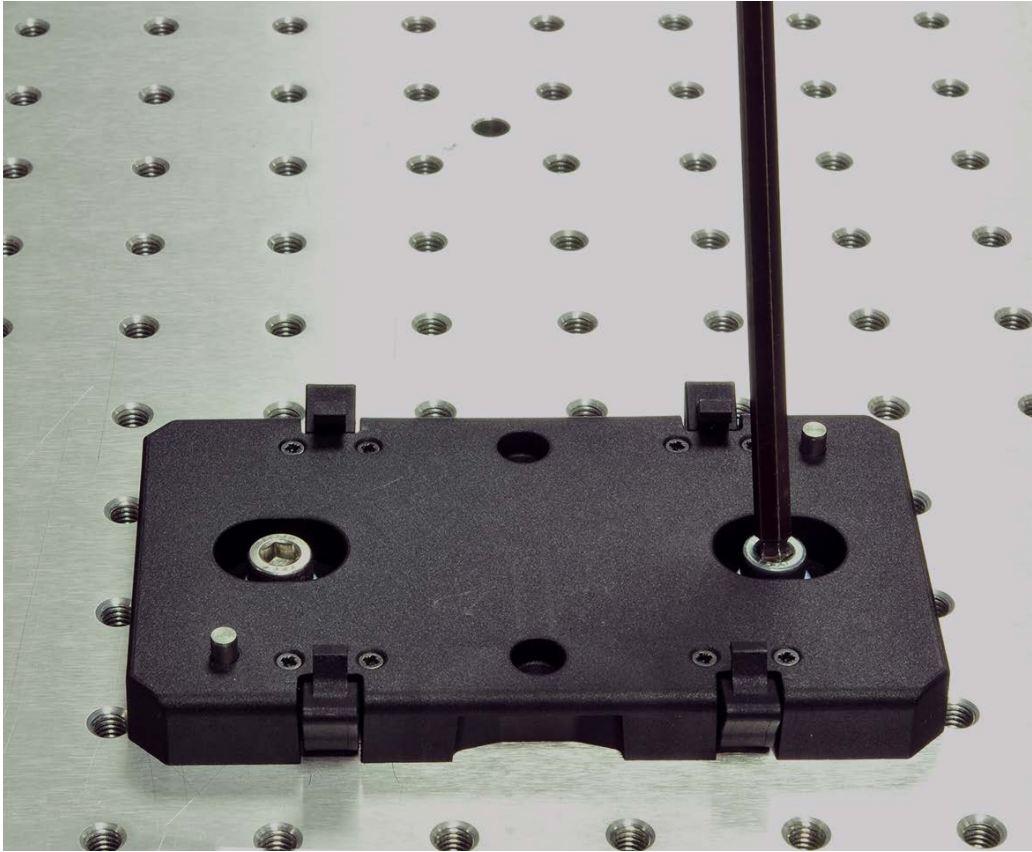


Fig. 3.1 Using The Baseplate

3.3 Electrical Installation

3.3.1 Rear Panel

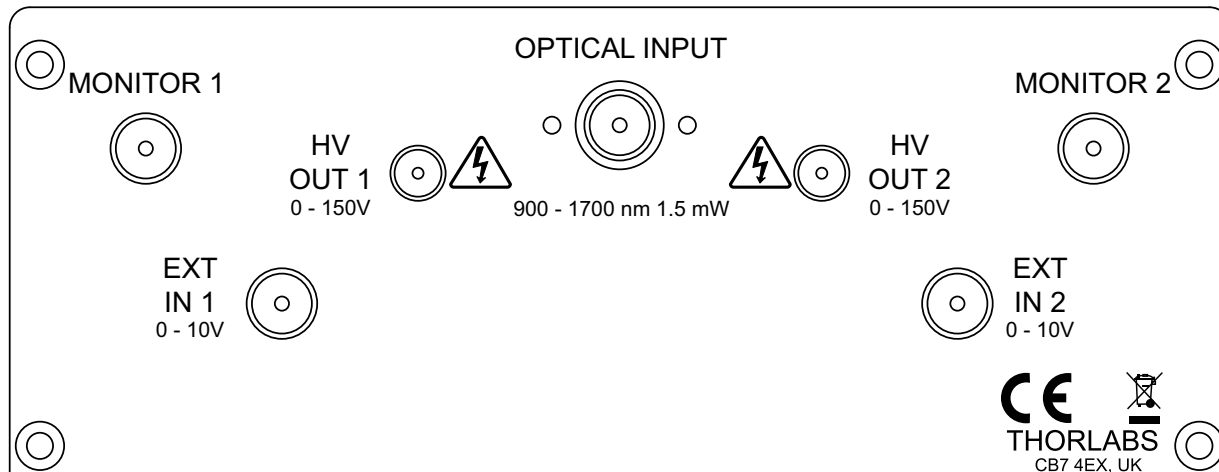


Fig. 3.2 Rear Panel Connections

OPTICAL INPUT — The KNA-IR is fitted with a FC/PC connector that incorporates an InGaAs Infra Red detector. The KNA-VIS incorporates a visible spectrum silicon photodiode - see Section 3.4. for more details. To receive a signal from a PIN diode, as incorporated in external detector heads, the front panel IO 1 terminal can be used - see Section 3.3.2.

EXT IN (SMA connector) — Used to receive a piezo feedback signal from signal source such as the K-Cube KSG101 Strain Gauge Reader; 0 to 10 V range, 10 k Ω input impedance.

HV OUT (SMC connector) — 0 to 150 V. These outputs provide the drive signal to the associated piezo actuators. The max voltage is set to 75 V or 150 V in software, see Section 5.4.2.

MONITOR — These outputs mirror the associated HV OUT, 10 V being equivalent to maximum voltage on the HV outputs, and can be connected to an oscilloscope to enable the drive signal of the piezo actuator to be monitored.

3.3.2 Front Panel



Warning

The unit must be connected only to a DC supply as detailed in Section 3.3.3.. Connection to a supply of a different rating may cause damage to the unit and could result in injury to the operator.

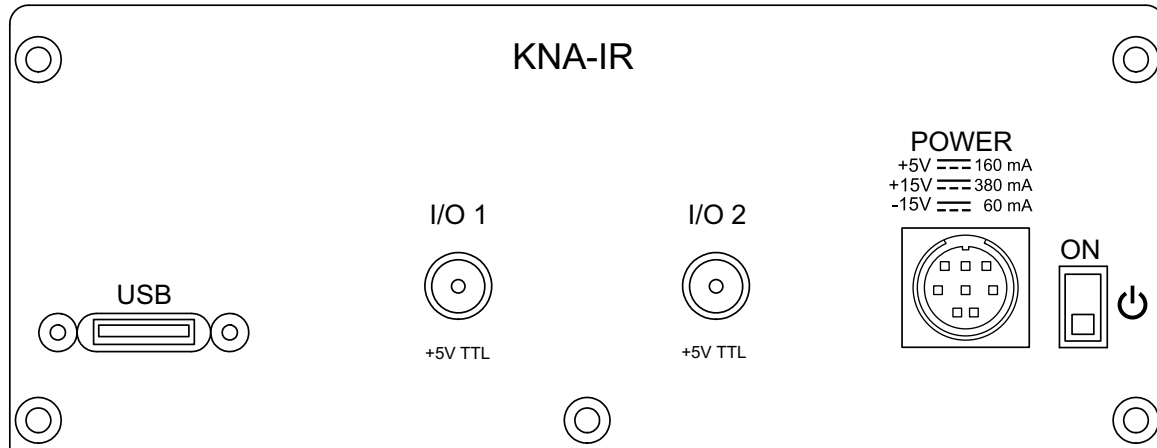


Fig. 3.3 Front Panel Connections

POWER — Eight pin connector for connecting the unit to a regulated DC power supply of the rating detailed in Section 3.3.3.

USB — USB port for system communications.

Note

The USB cable length should be no more than 3 metres unless a powered USB hub is being used.

ON — Power ON/Standby switch. When in the ON position, the unit is fully powered up. When the switch is turned to the Standby position, the unit initiates a controlled power down sequence, saving all user-adjustable parameters to non-volatile memory before turning off the power. For the first few seconds, the shutdown can be cancelled by turning the switch on again, in which case the unit will save the parameters but will remain powered up. In a powered down (Standby) state, the logic circuits are powered off and the unit will draw only a small quiescent current. The switch should always be used to power down the unit.

I/O 1 (SMA connector) — This output is dual purpose. It can be used as a Trigger Input/Output (0 to 5 V), or as a External Input (0 to 2 V). When used as an external input, the input signal is amplified and presented as a drive signal at the HV OUT connectors on the rear panel.

I/O 2 (SMA connector) — This output is dual purpose. It can be used as a Trigger Input/Output (0 to 5 V), or as a External output (0 to 2 V) (e.g. for use in a dual NanoTrak set up - see Section 5.5.2.).

3.3.3 Supply Voltage and Current Requirements

Thorlabs offers a compact two-way power supply (TPS002) or the K-Cube hub (see Section 1.2. for more details) for use with the NanoTrak cube. Do not use power supplies by other manufacturers.

Supply	Minimum	Maximum	Max Operating Current
+5 V	+4.9 V	+5.1 V	160 mA
+15 V	+14.5 V	+15.5 V	380 mA
-15 V	-14.5 V	-15.5 V	60 mA



Caution

Although the TPS002 has two outputs, it should not be used to drive another K-Cube as well as the KNA unit. Doing so could exceed its current limits.

3.3.4 Typical System Connections

**Warning**

High voltages may be present at the rear panel terminals. Ensure that the power is switched off before making or breaking any electrical connections. In particular, the piezo 'HV OUT' terminals can carry up to 150 V

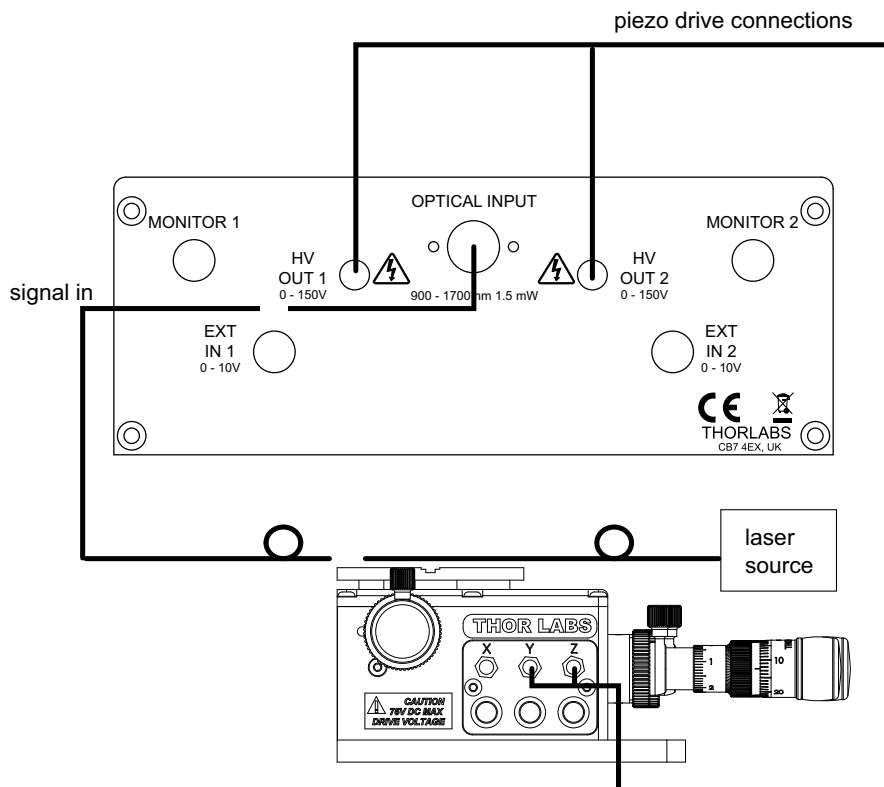


Fig. 3.4 Connecting the system

Example Set Up of the NanoTrak with the Stage and Optical Fibers

Referring to Fig. 3.4:

- 1) Make electrical connections as shown above.
- 2) Set up the optical fibers on the stage, using a V-groove holder or similar, such that the light can be transmitted between them. The incoming fiber carries light from a source such as a focussed HeNe laser or pigtailed laser diode. Ensure the fiber ends are clean and well cleaved.
- 3) If using the NanoTrak detector, connect the fiber to the OPTICAL INPUT. If using an external detector head, connect the output fiber to the detector head. Using the SMB-terminated cable, connect the detector head to the 'OPTICAL INPUT' connector of the NanoTrak.

3.4 Detector Heads and Cables

The OPTICAL INPUT terminal on the rear panel houses the detector/photodiode. The KNA-IR NanoTrak is supplied with an Infrared InGaAs photodiode, while the KNA-VIS ships with a visible spectrum Si photodiode. The units can also be used with external detector heads which incorporate a PIN (p-type/intrinsic/n-type) diode.

3.4.1 Using an External Power Meter

The internal power meter of the NanoTrak is not calibrated, and external power meters are available that may give greater sensitivity and accuracy. If this is required, the output of the detector should be connected to the power meter, and the power meter output connected to the 'I/O 1' connector on the front panel of the NanoTrak. The Input Source should also be set to I/O 1 in the Settings Menu (see Section 4.2.6.) or to 2 V SMA in the GUI Settings Panel (see Section 5.4.2.).

Note

Use only an external power meter which gives a true analog output and does not introduce any phase shift into the system. Some power meters give a smoothed output only suitable for driving a chart recorder.

3.5 Connect The Hardware

- 1) Perform the mechanical installation as detailed in Section 3.2.
- 2) Connect the various system components - see Section 3.3.4.



Caution

During items (3) to (6) the instructions should be followed in the order stated. Problems may occur if the process is not performed in the correct sequence.

- 3) Install the Software.
- 4) Connect the NanoTrak unit to your PC.

Note

The USB cable length should be no more than 3 m unless a powered USB hub is being used.



Caution

During item (5) ensure the power switch on the front panel of the unit is switched off before connecting power to the K-Cube. Always power up the K-Cube unit by its ON switch. DO NOT connect the K-Cube unit to a 'live' external power supply. Doing so (i.e. "hot plugging") carries the risk of PERMANENT damage to the unit. Similarly, to power down the unit, turn the power switch off before disconnecting the power supply.

- 5) Connect the Controller unit to the power supply - see Section 3.3.
- 6) Connect the PSU to the main supply.
- 7) Switch 'ON' the unit using the switch on the front panel.
- 8) The Windows® OS should detect the new hardware. Wait while the drivers are installed for the new hardware.

The unit takes about 5 seconds from power application until warm up is finished, during which time the following screen is displayed.

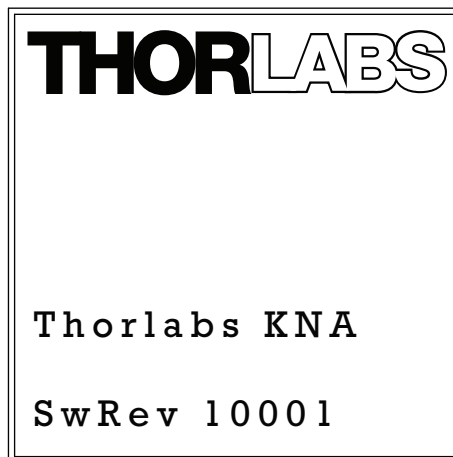


Fig. 3.5 KNAxxx start up screen

Note

If any problems are encountered during the connection and power up process, power cycle the unit, which should clear the error.

For best accuracy, wait approximately 30 mins for the unit to thermally stabilize to the environment.

Chapter 4 Standalone Operation

4.1 Control Panel Buttons and Indicators

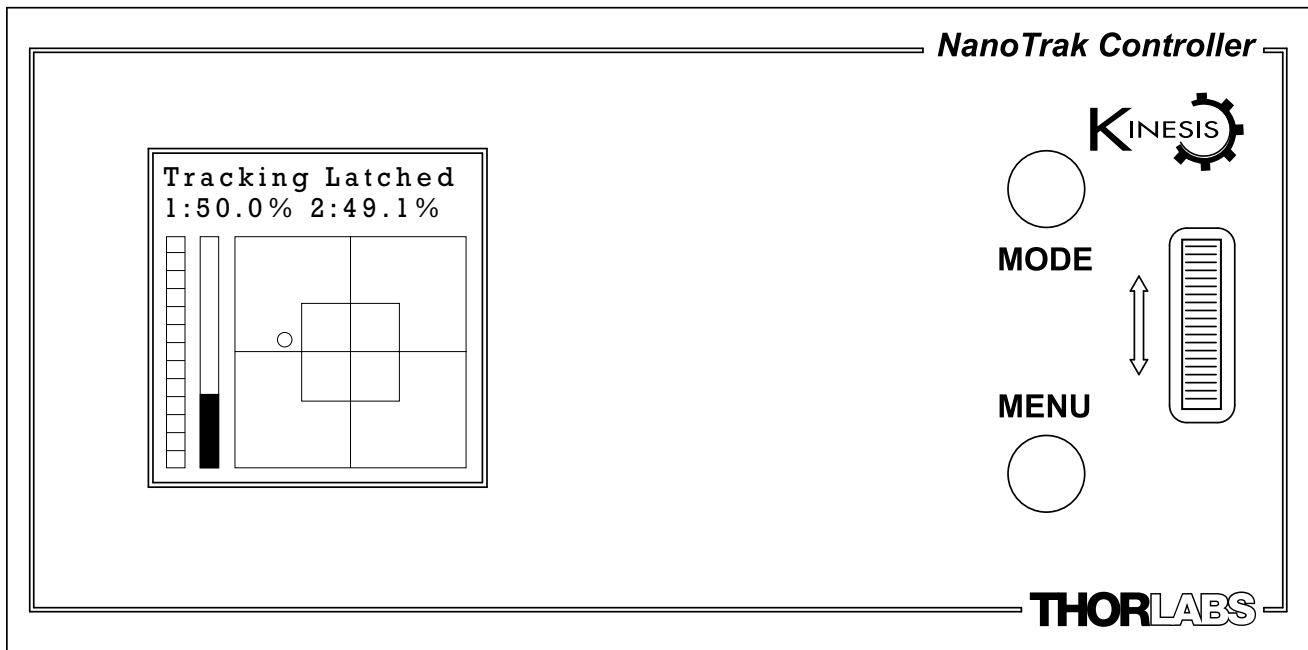


Fig. 4.1 Panel Controls and Indicators

Wheel — Used to scroll through the setting menu options - see Section 4.2.

Digital Display — The display shows the menu options and settings, accessed via the menu button - see Section 4.2. When the Ident button on the associated GUI panel is clicked, the display will flash for a short period.

MENU — Used to access the settings menu - see Section 4.2.

MODE Button — Switches between Latch and Track operating mode - see Section 4.1.1.

4.1.1 MODE Button Operation

The MODE button is used to switch between Latch and Tracking modes. When in 'TRACK' mode, the NanoTrak detects any drop in signal strength resulting from misalignment of the input and output optical devices, and makes positional adjustments (output DC offsets) to maintain maximum throughput.

When in 'LATCH' mode, scanning is disabled and the piezo drives are held at their present position (DC offsets fixed and no sinusoidal dithering, i.e. the piezo actuators are stationary). The top panel display shows 'Tracking Latched' when 'LATCH' mode is selected.

4.1.2 Digital Display - Operating Mode

During normal operation, the digital display (see Fig. 4.1) shows the drive output voltage as a percentage of full range for each output channel. If Latch mode is selected, it also shows a 'Tracking Latched' message. The 'Target' graph gives a visual representation of the position of the output actuators in XY space. It also shows two bar graphs which represent the range of the internal power meter and the located power level in relation to the range.

4.2 Overview

After the power up sequence is complete, the normal operating screen is displayed.

Press the MENU button to enter the settings mode.
 Use the wheel to scroll through the menu options.
 Press the MENU button to enter a particular option.

Home the outputs - see Section 4.2.1.

Set the Output Voltage for HV OUT 1 - see Section 4.2.2.

Set the Output Voltage for HV OUT 2 - see Section 4.2.3.

Enable the HV outputs - see Section 4.2.4.

Set the max output voltage of the HV outputs - see Section 4.2.5.

Select the optical power source - see Section 4.2.6.

Turn the external output I/O 2 ON - see Section 4.2.7.

Set the Latch mode of HV outputs- see Section 4.2.8.

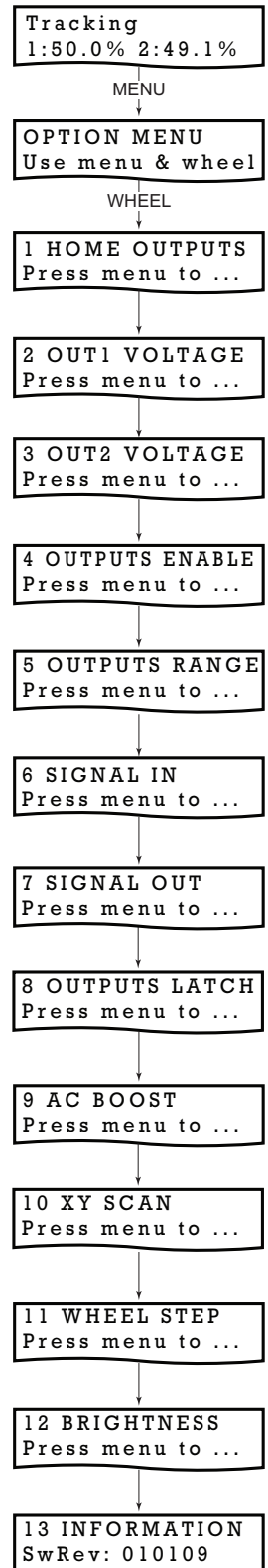
Turn AC Boost ON - see Section 4.2.9.

Turn the XY Scan ON - see Section 4.2.10.

Set the wheel adjustment rate- see Section 4.2.11.

Set the display brightness - see Section 4.2.12.

Display information - see Section 4.2.13.



4.2.1 Menu Option - 1 HOME OUTPUTS

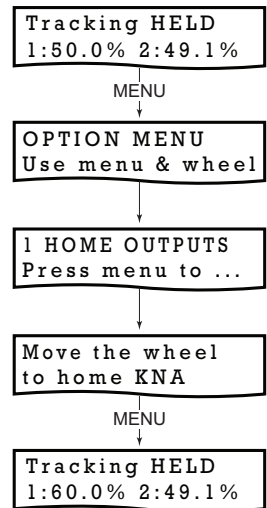
This option is used to 'HOME' the output from the HV OUT connectors. The outputs are reset to 50% of the maximum value set in the 6 OUTPUTS RANGE option, see section Section 4.2.5.

Press the MENU button, then use the wheel to scroll through the menu options

Press the MENU button to enter the 1 HOME OUTPUTS option.

Use the wheel to reset the outputs.

Press MENU to save the setting.



4.2.2 Menu Option - 2 OUT1 VOLTAGE

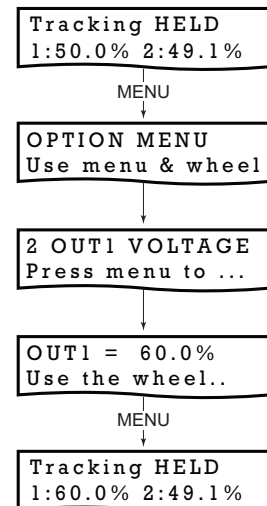
This option is used to set the drive voltage output from the HV OUT 1 connector, as a percentage of max voltage.

Press the MENU button, then use the wheel to scroll through the menu options

Press the MENU button to enter the 2 OUT1 VOLTAGE option.

Use the wheel to set the required voltage (as a percentage of max voltage) in the range 5% to 95%.

Press MENU to save the setting.



4.2.3 Menu Option - 3 OUT2 VOLTAGE

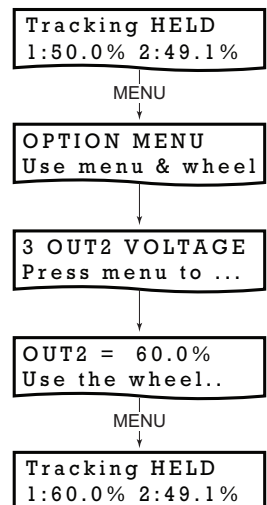
This option is used to set the drive voltage output from the HV OUT 2 connector, as a percentage of max voltage.

Press the MENU button, then use the wheel to scroll through the menu options

Press the MENU button to enter the 3 OUT2 VOLTAGE option.

Use the wheel to set the required voltage (as a percentage of max voltage) in the range 5% to 95%.

Press MENU to save the setting.



4.2.4 Menu Option - 4 OUTPUTS ENABLE

This option is used to enable and disable the drive voltage output from the HV OUT connectors.

Press the MENU button, then use the wheel to scroll through the menu options

Press the MENU button to enter the 4 OUTPUTS ENABLE option.

Use the wheel to enable or disable the output.

Note

Using the APT software, the output from each HV OUT connector can be enabled and disabled separately and in this case, the display will show OUTPUTS: SW MIXED - see Section 5.4.2. for more details.

Press MENU to save the setting

4.2.5 Menu Option - 5 OUTPUTS RANGE

This option is used to set the maximum drive voltage output from the HV OUT connectors.

Press the MENU button, then use the wheel to scroll through the menu options

Press the MENU button to enter the 5 OUTPUTS RANGE option.

Use the wheel to set the max the output voltage, 75 V or 150 V.

Press MODE to save the setting and return to the set up menu.

Note

The factory default setting is 75 V.

Using the APT software, the maximum output voltage can be set to different values for each HV OUT connector and in this case, the display will show RANGES: SW MIXED, see Section 5.4.2. for more details.

Press MENU to return to the operating mode.

4.2.6 Menu Option - 6 SIGNAL IN

This option is used to set the optical power source input.

Press the MENU button, then use the wheel to scroll through the menu options

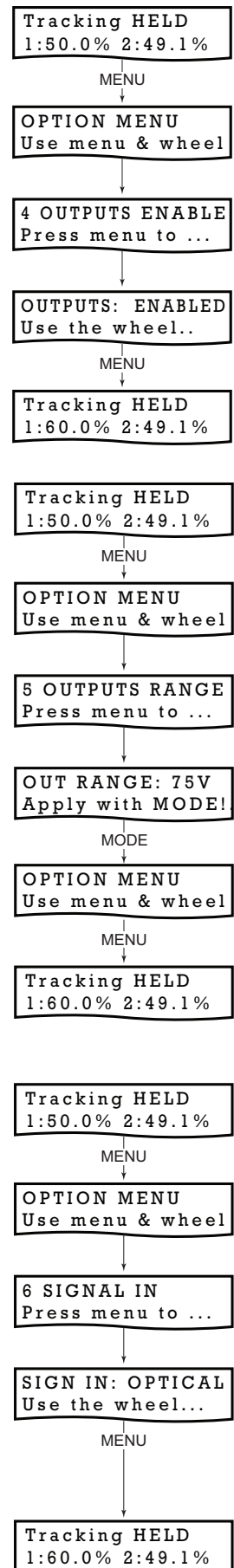
Press the MENU button to enter the 6 SIGNAL IN option.

Use the wheel to select the input source required, *OPTICAL* or *I/O 1*.

The *OPTICAL* Input option should be used when NanoTraking to optimise a current feedback signal using the rear panel OPTICAL INPUT connector. This option uses the internal TIA (trans-impedance amplifier) circuit and associated functionality (e.g. autoranging).

The *I/O 1* Input option should be used when NanoTraking to optimise a voltage feedback signal connected to the front panel I/O 1 SMA connector (2 V max). Typically, these inputs are selected when using an external power meter (e.g. PM100D) which generates a voltage output. In this case the internal amplifier circuit is bypassed and ranging functionality (as displayed on the GUI) is inoperative.

Press MENU to save the setting.



4.2.7 Menu Option - 7 SIGNAL OUT

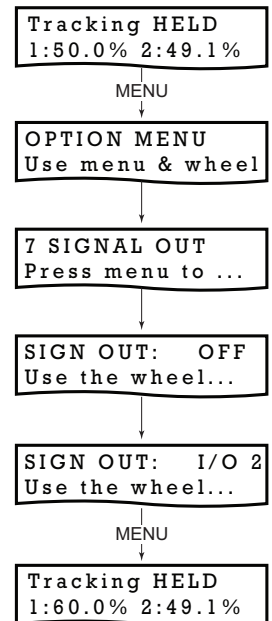
The internal piezo drivers of the KNA unit are limited to an output current of around 5 mA, which is insufficient for some of the higher circle scanning frequencies available. In this case it will be necessary to route the output signals from the NanoTrak K-Cube to an external piezo driver that has a higher operating bandwidth. This option allows the NanoTrak cube to be used with external piezo drivers, whereby the I/O 2 connector on the front panel can be configured as an external output. and the power signal is output as a 0 to 2 V signal via this SMA connector.

Press the MENU button, then use the wheel to scroll through the menu options

Press the MENU button to enter the 7 SIGNAL OUT option.

Use the wheel to select OFF or I/O 2 as required.

Press MENU to save the setting.



4.2.8 Menu Option - 8 OUTPUTS LATCH

When the maximum power has been located, the unit is usually switched to latch mode to hold the position. However, due to environmental temperature and other factors, the piezos can drift over time. This menu option allows a FEEDBACK mode to be selected, whereby a feedback loop is employed. Any drift from the desired position is corrected and the maximum power position maintained.



Caution

FEEDBACK operation is only possible if an external position reader (such as the KSG101 Strain Gauge Reader) is used in conjunction with the KNA unit. If the KNA unit is switched to FEEDBACK mode without being connected to a Strain Gauge Reader, the unit will expect a feedback signal and the piezo drive voltage will ramp up to the maximum limit, either 75 V or 150 V, whichever is selected in the Input/Output tab.

This option is used to set the latch mode for both output channels.

Press the MENU button, then use the wheel to scroll through the menu options

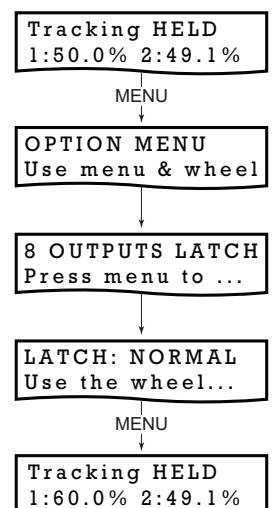
Press the MENU button to enter the 8 OUTPUTS LATCH option.

Use the wheel to select either NORMAL or FEEDBACK as required.

Note

Using the APT software, the latch mode can be set to different values for each HV OUT connector and in this case, the display will show LATCH: SW MIXED, see Section 5.4.2. for more details.

Press MENU to save the setting.



4.2.9 Menu Option - 9 AC BOOST

At low signal levels, when scanning for optical power, a small change in circle position can result in a large change in power reading. As the search gets closer to the max power position, changes in circle position result in only small changes in power reading. When enabled, the AC BOOST option amplifies the difference in power reading to better emphasise the direction of max power.



Caution

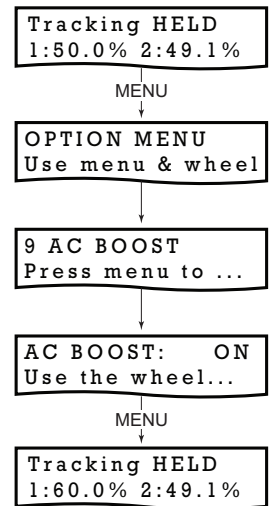
AC BOOST mode is normally disabled because amplifying the power reading can result in instability and alignment to false power peaks. It should only be used in applications where the max power position can be estimated with some degree of accuracy.

Press the MENU button, then use the wheel to scroll through the menu options

Press the MENU button to enter the 9 AC BOOST option.

Use the wheel to select either ON or OFF as required.

Press MENU to save the setting.



4.2.10 Menu Option - 10 XY SCAN

In some applications, it may be useful to know roughly where the high power region is located within the travel range of the piezo devices (e.g. to avoid power optimization on a side peak). When the XY SCAN is selected, the K-Cube unit moves the stage in an XY raster scan pattern over the full piezo range, and measures the optical power in a grid 96 x 96 points. The power data is then shown as an intensity map, 96 pixels x 96 pixels.

During the scan, auto-ranging is disabled, and the range is locked at the range in use when the Scan was started. See Section 4.3. for more details.

Press the MENU button, then use the wheel to scroll through the menu options

Press the MENU button to enter the 10 XY SCAN option.

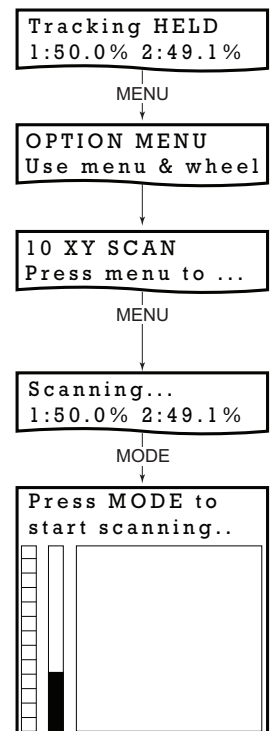
The scan starts automatically.

The unit performs the XY Scan, and display the result as a 96 px x 96 px map.



Press the MODE button to perform another scan, or press the MENU button to return to the set up menu.

Press the MENU button again to return to the operating mode.



4.2.11 Menu Option - 11 WHEEL STEP

This option is used to set/change the adjustment rate of the top panel wheel.

Press the MENU button, then use the wheel to scroll through the menu options

Press the MENU button to enter the 11 WHEEL STEP option.

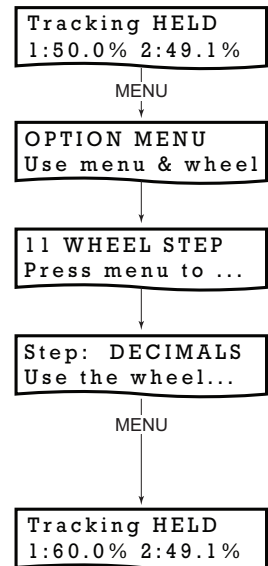
Use the wheel to select the required adjustment, DECIMAL, UNITS or DECADES.

DECIMAL - Adjusts the least significant digits
(e.g. 0.1, 0.2, 0.3 etc).

UNITS - Adjusts the units digits (e.g. 1, 2, 3 etc).

DECADES - Adjusts the most significant digits
(e.g. 10, 20, 30 etc).

Press MENU to save the setting.



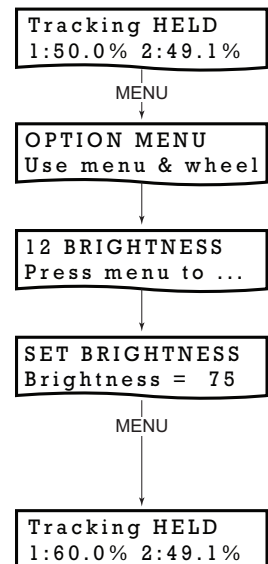
4.2.12 Menu Option - 12 BRIGHTNESS

In certain applications, it may be necessary to adjust the brightness of the LED display. The brightness is set as a value from 0 (Off) to 100 (brightest). The display can be turned off completely by entering a setting of zero, however, pressing the MENU button on the top panel will temporarily illuminate the display at its lowest brightness setting to allow adjustments. When the display returns to its default operating display mode, it will turn off again.

Press the MENU button, then use the wheel to scroll through the menu options.

Press the MENU button to enter the 12 BRIGHTNESS option.

Use the wheel to adjust the brightness, then press the MENU button to store the selection and return to the main display.



4.2.13 Menu Option - 13 INFORMATION

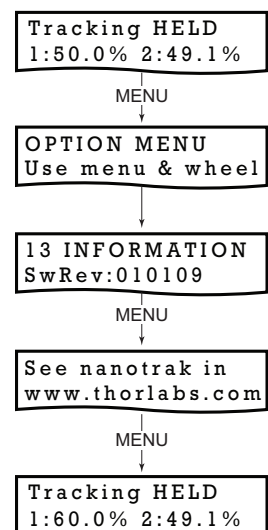
This option is used to display the present Software version number.

Press the MENU button, then use the wheel to scroll through the menu options.

The INFORMATION option displays the revision of the software installed in the unit.

Press the MENU button to enter the 13 INFORMATION option and view the Thorlabs web site address.

Press the MENU button to return to the main display.



4.3 XY Scan Mode

In some applications, it may be useful to know roughly where the high power region is located within the travel range of the piezo devices (e.g. to avoid power optimization on a side peak). When the XY SCAN is selected, the K-Cube unit moves the stage in an XY raster scan pattern over the full piezo range, and measures the optical power in a grid 96 x 96 points. The power data is then shown as an intensity map, 96 pixels x 96 pixels.

The scan can be initiated from the top panel setup menu (see Section 4.2.10.), from the Diagnostics tab on the GUI Settings panel (see Section 5.5.) or via a software method call (see the online help file).

During the scan, auto-ranging is disabled, and the range is locked at the range in use when the Start Scan button was pressed.

The bar graph shows a visual representation of the power intensity range, from 0 to 100% such that a comparison with the scan values can be achieved.

4.4 Creating a Simulated Configuration Using APT Config

The 'APT Config' utility can be used to set up simulated hardware configurations and place the APT Server into simulator mode. In this way it is possible to create any number and type of simulated (virtual) hardware units in order to emulate a set of real hardware. This is a particularly useful feature, designed as an aid learning how to use the APT software and as an aid to developing custom software applications 'offline'.

Any number of 'virtual' control units can be combined to emulate a collection of physical hardware units. For example, an application program can be written, then tested and debugged remotely, before running with the hardware.

To create a simulated configuration proceed as follows:

- 1) Run the APT Config utility - Start/All Programs/Thorlabs/APT/APT Config.
- 2) Click the 'Simulator Configuration' tab.

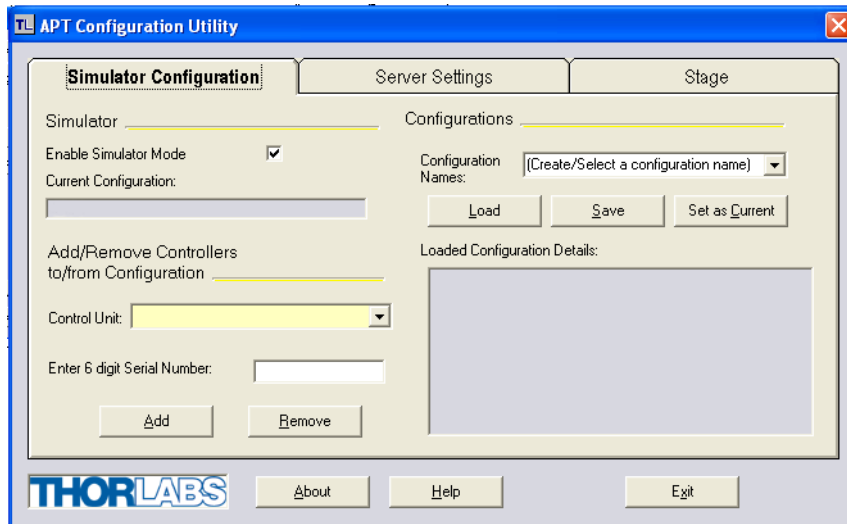
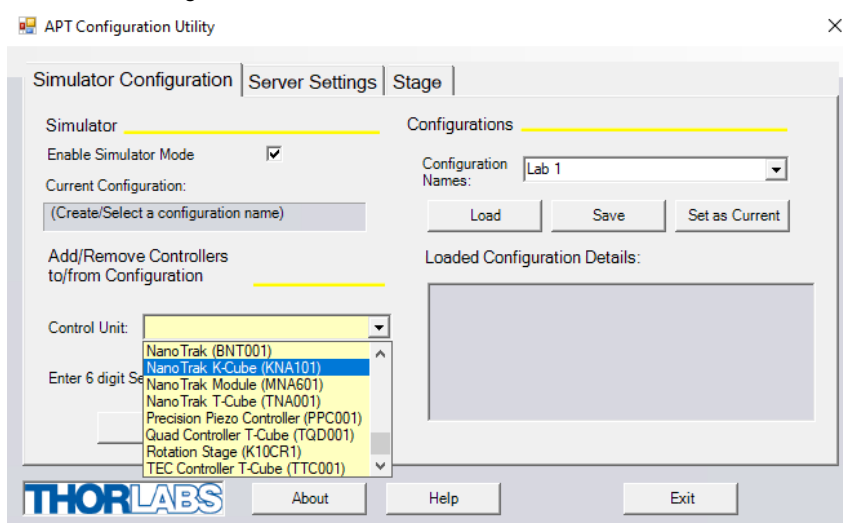
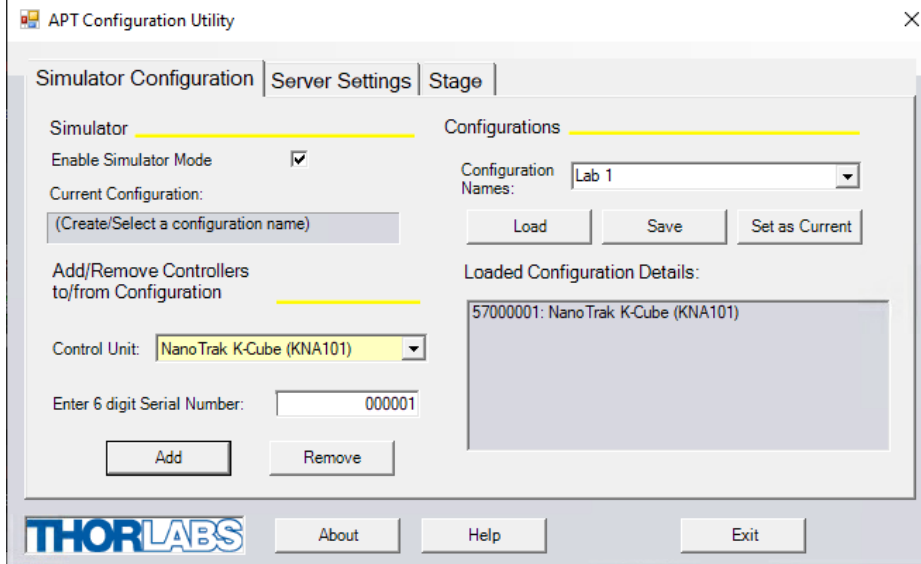


Fig. 4.2 APT Configuration Utility - Simulator Configuration Tab

- 3) Enter 'LAB1' in the Configuration Names field.
- 4) In the 'Simulator' field, check the 'Enable Simulator Mode' box. The name of the most recently used configuration file is displayed in the 'Current Configuration' window.



- 5) In the 'Control Unit' field, select 'NanoTrak K-Cube (KNA001)'.



- 6) Enter a 6 digit serial number.

Note

Each physical APT hardware unit is factory programmed with a unique 8 digit serial number. In order to simulate a set of 'real' hardware the Config utility allows an 8 digit serial number to be associated with each simulated unit. It is good practice when creating simulated configurations for software development purposes to use the same serial numbers as any real hardware units that will be used. Although serial numbers are 8 digits (as displayed in the 'Load Configuration Details' window), the first two digits are added automatically and identify the type of control unit.

The prefixed digits relating to the KNAXxx K-Cube NanoTrak Driver are:

57xxxxxx - K-Cube NanoTrak Driver

- 7) Click the 'Add' button.
- 8) Repeat items (1) to (7) as required. (A unit can be removed from the configuration by selecting it in the 'Loaded Configuration Details' window and clicking the 'Remove' button or by right clicking it and selecting the 'Remove' option from the pop up window).
- 9) Enter a name into the 'Configuration Names' field.
- 10) Click 'Save'.
- 11) Click 'Set As Current' to use the configuration.

4.5 Programmed Operation

Note

Familiarize yourself with operation of the NanoTrak from the GUI panel (see Section 5.2.) before attempting programmed operation.

The functionality required for a client application to control the NanoTrak unit is provided by the NanoTrak Control Object within the APT server, with manual operation being facilitated via the front panel buttons (see Section 4.2.) or via the GUI panel (see Section 5.2.).

The APT Software Server System has been designed to allow custom nanopositioning applications to be developed in a Microsoft Windows environment. The use of ActiveX interfacing technology means that programming of the unit can be achieved in any compatible language (LabVIEW, Visual Basic etc.) without the need for an extensive library of language-specific functions.

Using the methods and properties described in the *APTServer helpfile*, the NanoTrak K-Cube can be programmed as part of an automated alignment application - see the *APTServer helpfile* for more details on the various methods.

Chapter 5 PC Operation - Tutorial

5.1 Introduction

The following brief tutorial guides the user through a typical series of actions and parameter adjustments performed using the PC based software. It assumes that the unit is electrically connected as shown in Section 3.3. and that the Software is already installed - see Section 3.1.

5.2 Using the APT Software

The APT application allows the user to interact with any number of hardware control units connected to the PC USB Bus (or simulated via the APT Simulator utility). This program allows multiple graphical instrument panels to be displayed so that multiple units can be controlled. All basic operating parameters can be set through this program, and all basic operations (such as switching between latch and tracking modes) can be initiated. Hardware configurations and parameter settings can be saved to a file, which simplifies system set up whenever the software is run up.

This tutorial shows how the application provides all of the functionality necessary to operate the hardware.

5.2.1 Initial Setup

- 1) Install the software as detailed in Section 3.1.
- 2) Connect the controller to the actuators (see Section 3.3.4.) and the PC, then switch ON. Wait approximately 5 seconds for the system to settle.



Caution

In applications requiring the highest level of accuracy and repeatability, it is recommended that the controller unit is powered up approximately 30 minutes before use, in order to allow the internal temperature to stabilize.

- 3) Run the software and check that the Graphical User Interface (GUI) panel appears and is active.

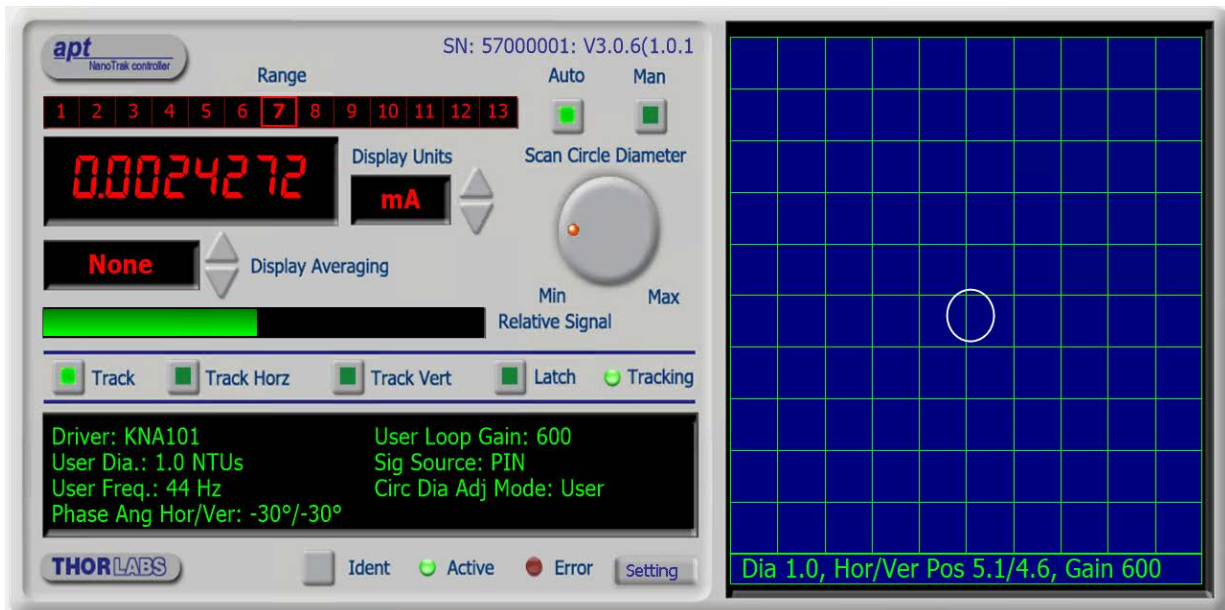


Fig. 5.1 NanoTrak software GUI

- 4) Click the 'Identify' button. The digital display of the associated controller flashes. This is useful in multi-channel systems for identifying which channel is associated with which GUI.

5.2.2 Description of GUI Panel Controls

Referring to Fig. 5.1.

Note

The serial number of the unit associated with the GUI control instance is displayed in the top right hand corner of the control.

Range Indicator — Displays the current range of the internal power meter. When operating in 'Manual' ranging mode, the range can be changed by clicking the required range number. Available ranges vary from 5 nA (range 1) to 5 mA (range 13) (when the display units are selected to mA - see below). Note that in many practical arrangements the lower ranges may be unusable with typical signal to noise ratios.

Average — Displays the averaging level being applied to the power readings (and the relative display bar) displayed on the GUI. Settings of 'low', 'medium' and 'high' resulting in averaging numbers of 5, 10 and 20 respectively. At the default display update rate of 10Hz, this translates to 0.5, 1 and 2 second time constants respectively. This setting is provided as a convenient way of smoothing readings displayed on the GUI only, and does not affect in any way those same readings when returned by software functions.

To change the setting, click the associated sector.

Units — Show the measurement units associated with the display.

If a PIN (TIA) input signal is connected (input source is set to TIA mode in the Input/Output settings tab), the display can be configured to display mA, mW or dB.

If 'mA' is selected, readings are displayed or returned as current in mA. The display shows the actual PIN current being detected by the PIN current amplifier.

If 'mW' is selected, readings are displayed or returned as power, generated using a Amp:Watt calibration factor specified either in the 'Settings' panel or by calling the associated software function.

Note

This is not intended to be a calibrated power reading, but rather a convenient mechanism for converting current to power. The conversion factor is typically wavelength specific.

If 'dB' is selected, readings are displayed or returned in dBs. The signal is first converted to Watts according to the calibration factor, and then into dB. Consequently, this conversion is also wavelength dependent.

If a SMA input is connected (input source is set to a SMA mode in the settings panel), the display can be configured to display 'V', '%' or 'User'.

If 'V' is selected, readings are displayed or returned in Volts, i.e. the raw input signal to the SMA connector.

If '%' is selected, readings are displayed or returned as a percentage of full scale input, e.g. a 1V signal into a 2V input range SMA will display a value of 50%.

If 'User' is selected, readings are displayed or returned as a calibrated value using a calibration factor set using the Voltage calibration parameter on the Input/Output tab of the Settings panel, e.g. if the calibration factor has been set to '20', a 1 V signal into a 2 V input range SMA will display a value of 10.

Digital Display — The main display shows the feedback signal level being measured.

The lower part of the display gives a convenient indication of the feedback signal level. When the input source is set to TIA (PIN), the display indicates the power level as a percentage of the currently applied range.

When the input source is set to SMA (voltage), then bar display indicates the voltage being measured. E.g. for an input voltage range of 2 V, a bar displaying half length equates to 1 V input signal.

Track — Push button control used to set the NanoTrak to 'Track' mode, using both horizontal and vertical axes to set a circular scan pattern. When tracking, the NanoTrak detects any drop in signal strength resulting from misalignment of the input and output devices, and makes positional adjustments to maintain the maximum. The LED in the button is lit when selected.

Latch — Push button control used to set the NanoTrak to latch mode, whereby scanning is disabled and the piezo drives are held at their present position. The LED in the button is lit when selected.

Horizontal — Push button control used to set the NanoTrak to track using a horizontal line scan pattern. The LED in the button is lit when selected.

Vertical — Push button control used to set the NanoTrak to track using a vertical line scan pattern. The LED in the button is lit when selected.

Auto and Manual — Push button control used to toggle between auto and manual ranging. The LED in the button is lit when selected.

Low Signal — Lit when the feedback signal level falls below the threshold set in the Tracking settings tab. This software threshold is set to reflect the signal levels at or above which the NanoTrak unit will be tracking at the position of the peak of the feedback signal. This threshold is typically set to lie above the 'noise floor' of the particular physical arrangement. Note that the low signal indicator does not apply when the input source is set to SMA (voltage) input.

Active LED — Lit when the unit is operating normally and no error condition exists.

Error LED — Lit when a fault condition occurs, i.e. either a power supply voltage is out of range, or a channel has closed loop mode selected but the associated piezo is disconnected.

Circle Position Display — Shows the position of the scan circle which in turn, corresponds to the horizontal and vertical position of the piezo actuators. The width and height of the display is 20 NanoTrak (NT) units, each division being 1/20th of the max piezo travel, (e.g. for a 20 μm piezo travel, 1 NT unit = 1 μm). Right click in the display to show the Circle Position window - see section Chapter 5.3.

Circle Diameter Control — Used to adjust the diameter of the scan circle, when operating in 'Manual' adjustment mode. The current diameter is displayed in the 'Settings' list. Note. Use of this control will automatically switch the circle diameter adjustment mode to 'Manual'.

Settings List — Shows user specified settings for the parameters listed below. **Note:** Some parameters can also be configured for automatic adjustment. When operating in the relevant 'Auto' mode, the user specified values displayed may be different to the actual values applied.

User Diameter — Displays the circle diameter (in NT units). The circle diameter can be set either by adjusting the manual control knob or by calling a software function.

Note

If the circle diameter adjustment mode is set to 'Auto', the actual circle diameter may be different to the diameter displayed in the Settings window. (see Section C.1.3. for further information).

Frequency — Displays the scanning frequency (in Hz). The scanning frequency can be set either by entering a value in the 'Settings' panel, or by calling a software function.

Phase Angle — Displays the phase compensation values (in degrees) for the horizontal and vertical components of the circle path. Values can be entered in the settings panel 'Tracking' tab. Note. If the phase compensation adjustment mode is set to 'Auto', the actual phase offset may be different to the diameter displayed. (see Section C.1.4. for further information).

Loop Gain — Displays the gain setting for the NanoTrak control loop. The gain can be set either by entering a value in the 'Tracking' settings panel.

Signal Source — Displays the type of input source connected. The input source is set by entering a value in the 'Input/Output' settings panel.

Diameter Mode — Displays the mode of circle diameter adjustment as follows:

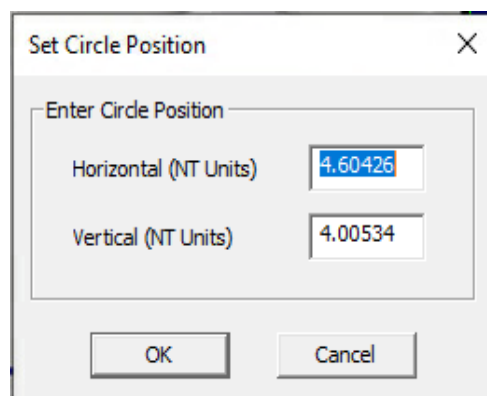
<i>User</i>	Diameter adjusted by the user
<i>LUT</i>	Diameter adjusted via Look Up Table (set via the Tracking tab).

Settings Button — Displays the 'Settings' panel, which allows the NanoTrak's operating parameters to be entered - see Section 5.4.

Identify — When this button is pressed, the display on the associated hardware module will flash for a short period.

5.3 Circle Position Window

Right click in the Circle Position Display, to show the position window.



This window shows the current circle position in whatever display units are selected, NanoTrak units or Microns. The circle can be positioned by entering a value into the X and/or Y fields and clicking the arrow.

5.4 Settings Panel

When the 'Settings' button on the GUI panel is clicked, the 'Settings' window is displayed. This panel allows data such as scan circle frequency and diameter, and loop gain to be entered. Note that all of these parameters have programmable equivalents accessible through the functions on this Control (refer to the *API helpfile* for further details).

5.4.1 Tracking tab

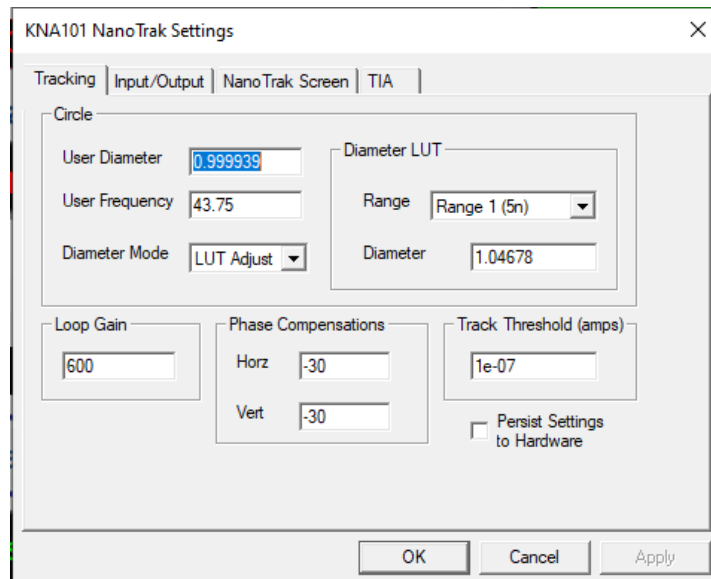


Fig. 5.2 NanoTrak Settings panel - Tracking Tab

Circle

User Diameter - the diameter of the scanning circle (in NanoTrak units). The circle diameter is measured on a scale such that 10 units is the width and height of the screen. If, for example, the NanoTrak is driving a 20 micron actuator, a circle diameter of 1 unit will result in a real diameter of 2 microns. The scanning circle diameter can have values in the range 0 to 5.0 with a value of 5.0 corresponding to one half the range of piezo motion - see Section C.1.3. for further details and helpful hints on setting the correct circle size.

User Frequency - the frequency of the scanning circle. The circle scanning frequency lies in the range 8.25 to 87.5Hz. The factory default setting for the scanning frequency is 43.75Hz. This means that a stage driven by the NanoTrak makes 43.75 circular movements per second. Different frequency settings allow more than one NanoTrak to be used in the same alignment scenario. Refer to Section 5.5.2. for more information.

Diameter Mode - this setting allows the different modes of circle diameter adjustment to be enabled and disabled.

If '**User Adjust**' is specified, the circle diameter remains at the value set by the user, either in the User Diameter parameter or by calling the SetCircDia method.

If '**LUT Adjust**' is specified, the circle diameter is adjusted automatically, using a table of range dependent diameter values (set in the Diameter LUT field to the right and described below (1 diameter per range value), or by calling the SetCircDiaLUTVal method).

Diameter LUT - this setting enables a look up table (LUT) of circle diameter values (in NanoTrak units) to be specified as a function of input range.

When automatic LUT diameter adjustment mode is enabled (using the Diameter Mode parameter or by calling the SetCircDiaMode method), the system uses values in this LUT to modify circle diameter in relation to the input range currently selected.

This LUT diameter adjustment mode allows appropriate circle diameters to be applied on an application specific basis. Typically, the circle diameter LUT will be configured to generate a reducing circle diameter for an increasing range setting. This fits an assumption that higher input signal readings correspond to a smaller Full Width Half Maximum (FWHM) of the feedback signal peak being tracked, and so a smaller circle diameter is required to prevent NanoTrak instability.

Range - the input range of the NanoTrak (1 to 13, corresponding to 5 nA to 5 mA respectively)

Diameter - the associated circle diameter (0 to 5 NT units).

Loop Gain - the gain setting is used to ensure that the DC level of the input (feedback loop) signal lies within the dynamic range of the input. Increasing this value can lead to a more responsive NanoTrak behavior as the signal variation around the circular path is enhanced. However, for a particular set up, if this value is too high, then unstable NanoTrak operation (indicated by a fluctuating circle) can result.

The gain value can be specified in the range 100 to 10,000 - see Section C.1.3. for further details and helpful hints on setting the loop gain.

Phase Compensations - the feedback loop scenario in a typical NanoTrak application can involve the operation of various electronic and electromechanical components (e.g. power meters and piezo actuators) that could introduce phase shifts around the loop and thereby effect the system stability. These phase shifts can be cancelled by setting a 'Phase Compensation' factor.

Horz - the phase compensation for the horizontal component of the circle path.

Vert - the phase compensation for the vertical component of the circle path.

The values can be specified in the range -180.0 to 180.0 degrees and typically are set equal to each other.

Track Threshold - the track threshold is set in Amps, and is dependent upon the application. Typically, the value is set to lie above the 'noise floor' of the particular optical arrangement. When the input signal level exceeds this value, the tracking LED is lit on the GUI panel. However, this is no guarantee that tracking is taking place. If the threshold value is set inappropriately, e.g. if the tracking threshold is set to below the noise floor, then the GUI will show a lit tracking LED even though no tracking is taking place.

The threshold setting can be obtained by calling the GetTrackThreshold method.

Persist Settings to Hardware - Many of the parameters that can be set for the NanoTrak T-Cube can be stored (persisted) within the unit itself, such that when the unit is next powered up these settings are applied automatically. This is particularly important when the driver is being used manually in the absence of a PC and USB link. The *User Diameter and Frequency* parameters described previously is a good example of a setting that can be altered and then persisted in the driver for use in absence of a PC.

To save the settings to hardware, check the 'Persist Settings to Hardware' checkbox before clicking the 'OK button.

5.4.2 Input/Output tab

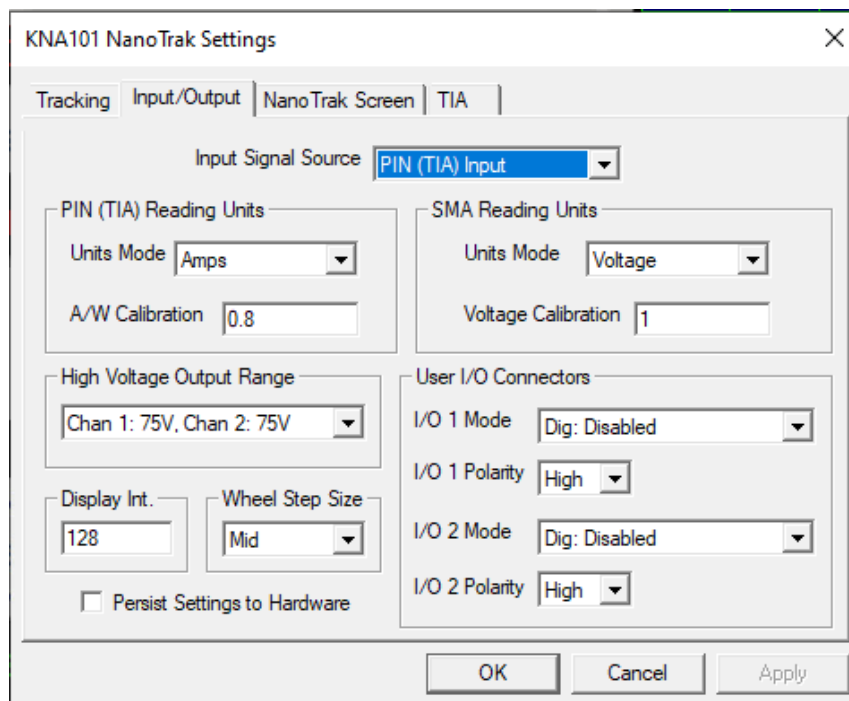


Fig. 5.3 NanoTrak Settings panel - Input/Output Tab

Input Signal

Input Signal Source - the input source can be set to PIN or a 2 V SMA input.

The *PIN (TIA)* Input option should be used when NanoTraking to optimise a current feedback signal using the rear panel OPTICAL INPUT connector. This option uses the internal TIA (trans-impedance amplifier) circuit and associated functionality (e.g. autoranging).

The *0-2 V SMA* Input option should be used when NanoTraking to optimize a voltage feedback signal fed into the IO1 connector on the front panel. Typically, these inputs are selected when using an external power meter (e.g. PM100D) which generates a voltage output. In this case the internal amplifier circuit is bypassed and ranging functionality (as displayed on the GUI) is inoperative. The input range is 0 to 2V.

PIN (TIA) Reading Units

Units Mode - this parameter specifies the units relating to the input signal measured by the NanoTrak, and is applicable only if a PIN (TIA) input source has been specified.

If *Amps* is selected, readings are displayed or returned in mA, i.e. the raw PIN current input signal to the internal amplifier.

If *Watts* is selected, readings are displayed or returned in mW, using a Amp:Watt calibration factor specified in the A/W Calibration parameter.

Note

This is not intended to be a calibrated power reading, but rather a convenient mechanism for converting current to power. The calibration factor will usually be a wavelength dependent property.

If *dB* is selected, readings are displayed or returned in decibels. The signal is first converted to watts according to the calibration factor specified in the A/W Calibration parameter, and then into dB.

A/W Calibration - the Amp:Watt calibration factor used when Watts or dBs is specified in the PIN Units Mode parameter.

SMA Reading Units

Units Mode - this parameter specifies the units relating to the input signal measured by the NanoTrak, and is applicable only if 0-2 V SMA input source has been specified.

If *Voltage* is selected, readings are displayed or returned in Volts, i.e. the raw input signal to the SMA connector IO 1 on the front panel.

If *% Full Range* is selected, readings are displayed or returned as a percentage of full scale input, e.g. a 1 V signal into a 2 V input range SMA will display a value of 50%.

If *User Defined* is selected, readings are displayed or returned as a calibrated value using the Voltage Calibration parameter, e.g. if Voltage Calibration has been set to '20', a 1 V signal into a 2 V input range SMA will display a value of 10.

Voltage Calibration - the calibration factor used when User Defined is selected in the Units Mode parameter.

High Voltage Output Range

The KNA K-Cube Nanotrak is designed with integrated High Voltage (HV) piezo drive outputs. The HV connectors 'HV OUT 1' and 'HV OUT 2' on the rear panel of the unit can be configured to have 75V or 150V maximum outputs. This dropdown list allows the HV output ranges to be selected. For example if Chan 1: 75V, Chan 2: 75V is selected then both HV outputs have a 75V limit. Similarly if Chan 1:75V, Chan 2: 150V is selected then 'HV OUT 1' and 'HV AMP 2' have maximum voltages of 75V and 150V respectively.

User IO Connectors

These parameters specify the operation of the User I/O (input/output) SMA connectors ('I/O 1' and 'I/O 2') on the front panel of the unit.

I/O 1 Mode, I/O 2 Mode - the user 'I/O 1' and 'I/O 2' connectors can be configured as digital (TTL) or analog (0 to 2V) signals. 'I/O 1' can only be configured as an analogue input and 'I/O 2' can only be configured as an analogue output. Both 'I/O 1' and 'I/O 2' can each be configured as digital (TTL) input or output.

The I/O modes available for 'I/O 1' and 'I/O 2' are:-

Dig: Disabled - the connector is set to a digital port but is disabled.

Dig In: Gen. Logic I/P - the connector is set to a general purpose digital input that can be read through software calls (see programming guides for details).

Dig In: Track/Latch - the connector is set to be a trigger input where active high sets 'Tracking' mode and active low sets 'Latch' mode.

Dig In: Circle to Home - the connector is set to be a trigger input where active high sends the circle to the home position (defaults to circle at screen center i.e. high voltage outputs at half range). The circle home position can be altered using software calls.

Dig Out: Gen. Logic O/P - the connector is set to a general purpose digital output that can be set through software calls.

Dig Out: Tracking Active - the connector is set to a trigger output where active high indicates active tracking (i.e. feedback signal above defined threshold - see 'Tracking' tab above).

In addition 'I/O 1' can be set to a 0-2V input by selecting *0-2V Input - F/B Source* and 'I/O 2' can be set to a 0-2V output by selecting *0-2V Output - F/B Monitor*.

Note - when set to an analog input the 'I/O 1' port is dedicated to be the external feedback signal input. Therefore if the 'Input Signal Source' (described above) is selected to be '0-2V SMA input' the mode for 'I/O 1' is automatically selected to be '0-2V Input - F/B Source'.

Note - when set to an analogue output the 'I/O 2' port is dedicated to be a monitor signal for the optical feedback source (at the current range setting for optical input i.e. equivalent to the relative signal bar on the main panel).

I/O 1 Polarity, I/O 2 Polarity - sets the polarity of the 'I/O 1' and 'I/O 2' connectors when in digital mode. A setting of 'High' means that logic high (TTL 5V) equates to active high. A setting of 'Low' means that logic low (TTL 0V) equates to active high.

Display Int. (Intensity) - Determines the brightness of the control panel display. Enter a value from 0 to 255.

Wheel Step Size - The thumbwheel on the to panel is used to control the HV outputs 'HV OUT 1' and 'HV OUT 2' selected using the menu system on the unit. This parameter sets the sensitivity of the thumbwheel to *Low*, *Mid* or *High*, where..

Low - Most turns of the thumbwheel to control output voltage (highest resolution)

High - Least turns of the thumbwheel to control output voltage (lowest resolution)

Persist Settings to Hardware - Many of the parameters that can be set for the NanoTrak K-Cube can be stored (persisted) within the unit itself, such that when the unit is next powered up these settings are applied automatically. This is particularly important when the driver is being used manually in the absence of a PC and USB link. The *Input Signal Source* parameter described previously is a good example of a setting that can be altered and then persisted in the driver for use in absence of a PC.

To save the settings to hardware, check the 'Persist Settings to Hardware' checkbox before clicking the 'OK button.

5.4.3 NanoTrak Screen tab

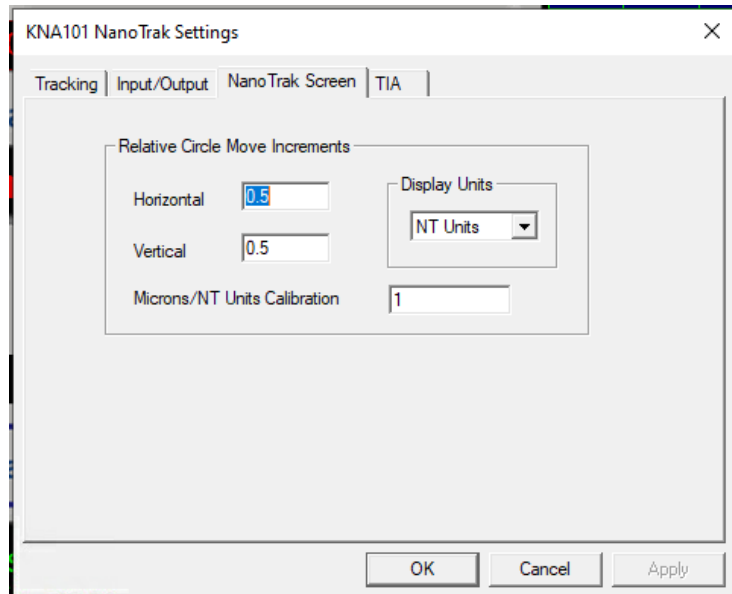


Fig. 5.4 NanoTrak Settings panel - Screen Tab

Sometimes, it may be useful to explore the response of the feedback signal by manually repositioning the two piezos driven by the NanoTrak. If desired, the NanoTrak circle can be positioned by using the mouse on the main panel display. This feature allows manual repositioning of the piezos, e.g. to enable investigation of the region of interest to look for side peaks, artifacts etc.

The circle can be moved either by click and drag, or by moving an incremental distances per mouse click.

Note. The circle can be moved in both Latch and Tracking modes

Relative Circle Move Increments:-

The circle can be positioned by clicking in the NanoTrak display screen. These parameters determine the distance moved per mouse click.

Horizontal & Vertical - the incremental distance can be set for each axis, in NT units or microns determined by the *Display Units* parameter. If *Display Units* is set to *NT Units*, the Horizontal and Vertical increments can be set from 0.01 to 2 NT units.

If *Display Units* is set to microns, the Horizontal and Vertical increment limits are dependent upon the travel of the piezo actuator - see the Microns/NT Units Calibration parameter.

Note. NanoTrak Screen Lower Display - The display at the bottom of the NanoTrak screen shows the circle diameter and the horizontal and vertical co-ordinates of the circle position. This information can be set to display in microns or NanoTrak units depending on the Display Units setting.



Microns/NT Units Calibration - If the Display Units parameter is set to microns, the 'Horizontal' and 'Vertical' Circle Move Increment limits are dependent upon the travel of the piezo actuator. This parameter is used by the NanoTrak to calculate the incremental limit per click, e.g. the NanoTrak screen is 10 units square, so for a 20 μ m piezo travel, 1 NT unit = 2 μ m. The NT Unit limits (described above) are 0.01 to 2, therefore the micron limits are 0.02 to 4 μ m.

5.4.4 TIA Tab

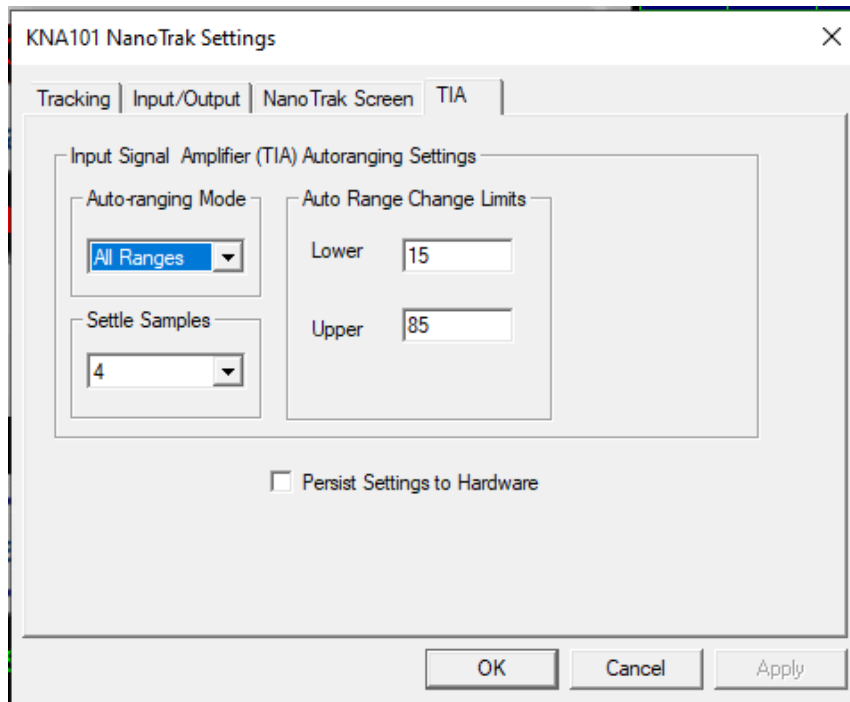


Fig. 5.5 NanoTrak Settings panel - Advanced Tab

Input Signal Amplifier (TIA Autorange Settings)

This panel is used to modify the autoranging and output characteristics of the NanoTrak input amplifier circuit (Trans-impedance amplifier (TIA) circuit).

Auto-ranging Mode - when auto-ranging mode is selected on the GUI panel, range changes occur whenever the input signal reaches the upper or lower end of the currently set range.

This parameter specifies how these range changes are implemented by the system.

If *All Ranges* is selected, the unit visits all ranges when ranging between two input signal levels.

If *Odd Ranges* (or *Even Ranges*) is selected, only those odd (or even) numbered ranges between the two input signals levels will be visited. These latter two modes are useful when large rapid input signal fluctuations are anticipated. This is because the number of ranges visited is halved to give a more rapid response.

Auto Range Change Limits - When autoranging, the NanoTrak unit continually adjusts the TIA range as appropriate for the input signal level. When the relative signal on a particular range drifts below the limit set in the 'Lower' parameter, the NanoTrak unit decrements the range to the next lower setting. Similarly, when the relative signal rises above the limit specified in the 'Upper' parameter, the unit increments the range to the next higher setting.

Settings are entered as a percentage of full range.

Note

The Upper limit must be higher than the Lower limit. If an attempt is made to enter a value for the Lower limit which is higher than the Upper limit, an error message is generated.

Settle Samples – This parameter determines the amount of averaging applied to the signal before autoranging takes place. Higher Settle Samples values improve the signal to noise ratio when dealing with noisy feedback signals. However, higher Settle Samples values also slow down the autoranging response. In a particular application, the Settle Samples value should be adjusted to obtain the best autoranging response combined with a noise free signal.

Values can be set from '2' to '32', with a default setting value of '4'.

5.5 Programmed Operation - NanoTrak

Note

Familiarize yourself with NanoTrak operation from the GUI panel before attempting programmed operation from the Controller PC.

5.5.1 A Typical Alignment using the NanoTrak

- 1) In the NanoTrak GUI, set the 'Scan Circle Diameter' control to approximately mid-position.
- 2) Press the 'Latch' button to select Latch mode and check that the Latch indicator LED is lit.
- 3) Click and drag to center the scan circle in the display.
- 4) Press the 'Auto' button to select 'Auto' mode. Ensure that the 'Auto' LED is lit.
- 5) Adjust the actuator on the positioning stage such that the fibers are spaced well apart, with zero power transmission between them. (Alternatively, switch off or obscure the optical power source). Make a note of the bar graph displays of relative power input and range. Since the optical source has been removed, only background noise is registered.
- 6) Use the actuators to bring the fiber tips together, until the display shows a significant increase indicating that the power has risen above the background level.
- 7) Press the 'Track' button to select Track mode. Check that the 'Tracking' indicator is lit and that the circle moves towards the position of maximum power (center screen). The NanoTrak has now positioned the fiber to give the maximum optical power transmission.

Note

If the circle reaches the edge of the display, this means that the piezo actuators cannot move far enough to reach the position of maximum power. The horizontal and vertical actuators should be adjusted to bring the circle away from the edge of the screen – see Fig. 3.8.

If the circle tends to drift, increase the scan circle diameter, if the circle tends to oscillate, decrease the scan circle diameter.

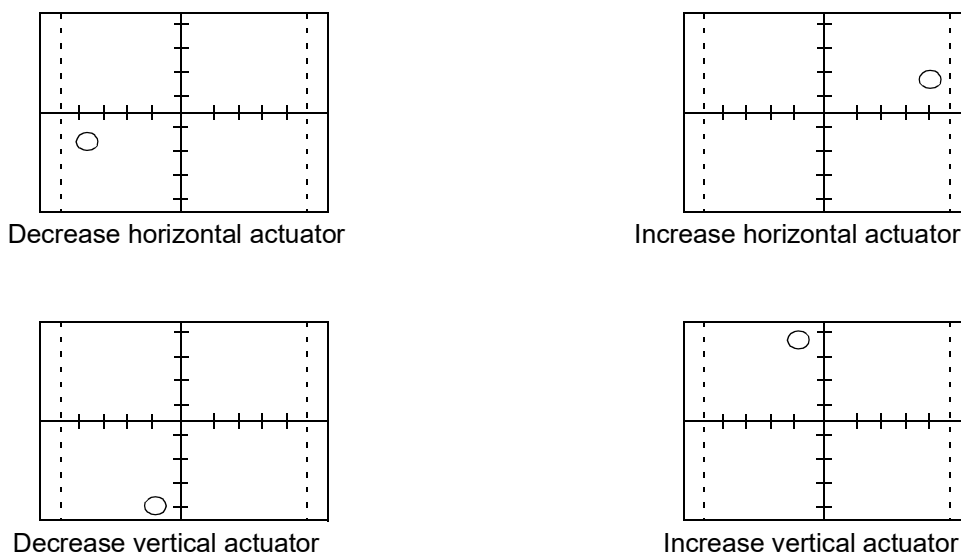


Fig. 5.6 NanoTrak displays and actuator adjustments

5.5.2 Using Two NanoTraks in the Same System

The NanoTrak scanning process uses a single frequency (and a highly selective discriminator similar to a radio receiver). It is possible to use more than one NanoTrak controller in a single optical path (and with a single detector). For example, with two control units set to different scanning frequencies (e.g. 30 Hz and 40 Hz) it is possible to couple fibers both into (master NanoTrak) and out of (slave NanoTrak) an integrated optical device such as a waveguide – see Fig. 5.7. The scan frequency and input source can be set either via the application software (see *API Helpfile*) or directly via the Settings panel – see Section 5.4.1.

To set up a two NanoTrak system:

- 1) Make connections as shown in Fig. 5.7.
- 2) Power up the NanoTrak units.
- 3) Run the software.
- 4) In the master NanoTrak GUI, select 'Settings'.
- 5) Select the 'Tracking' tab, then set the Circle User Frequency, e.g. 40 Hz.
- 6) Select the 'Input/Output' tab, then set the Input Signal Source to 'PIN (TIA)'.

- 7) In the slave NanoTrak GUI, select 'Settings'.
- 8) Select the 'Tracking' tab, then set the Circle User Frequency, e.g. 30 Hz.

Note

A difference of at least 10 Hz is recommended between this frequency and that set at item (5). This is to ensure adequate frequency separation between the bandpass filters of the two NanoTraks.

- 9) Select the 'Input/Output' tab, then set the Input Signal Source to '2 V SMA'.

Note

With SMA input source selected, the internal TIA circuit is bypassed and therefore autoranging is not required. Also, the Tracking Indicator on the GUI panel is inoperative.

- 10) Set both NanoTraks to 'Track'.
- 11) Once alignment is achieved, tracking can be verified. Move the axes of the stage(s) by a small amount. The circle of the NanoTrak associated with the stage should move accordingly to follow the signal.

If using the internal power meter, the detector output is connected to the OPTICAL INPUT connector on the master unit and the signal to the slave NanoTrak must be routed from the master I/O 2 to the slave I/O 1. If using an external power meter, this is connected to I/O 1 on the master unit.

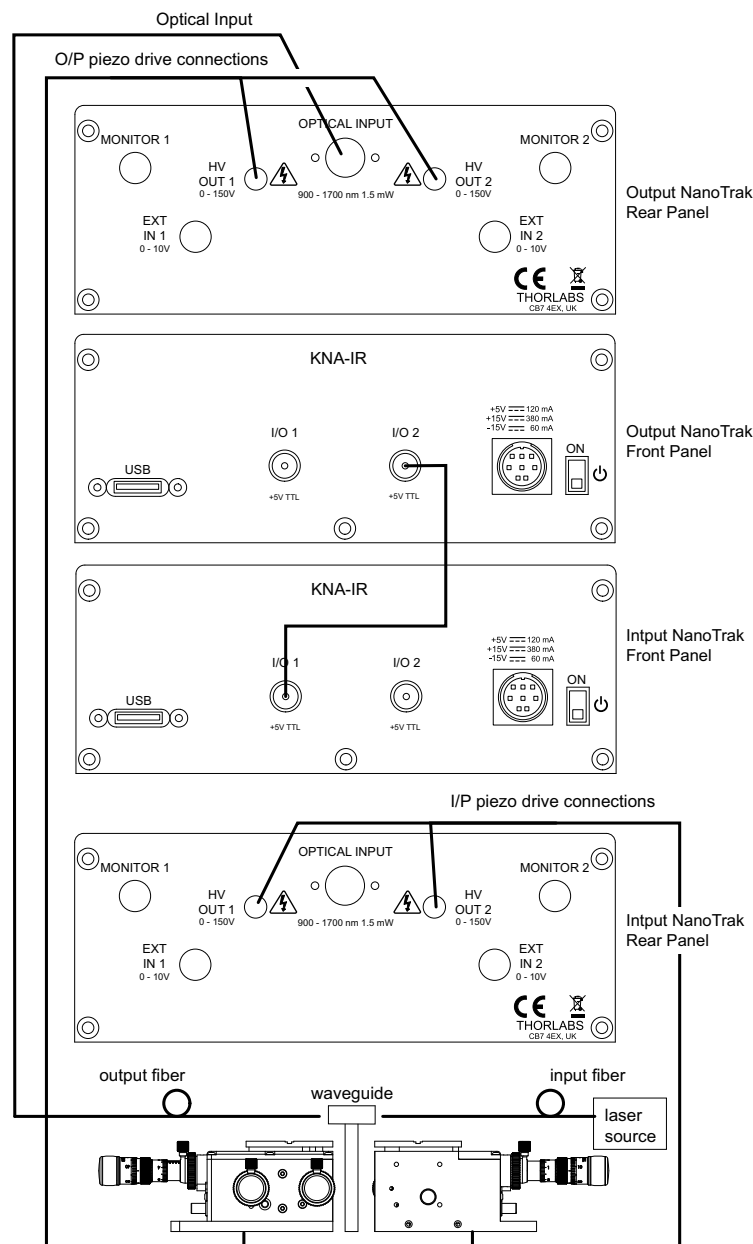


Fig. 5.7 Dual NanoTrak connections

An alternative option when using an external detector is shown below.

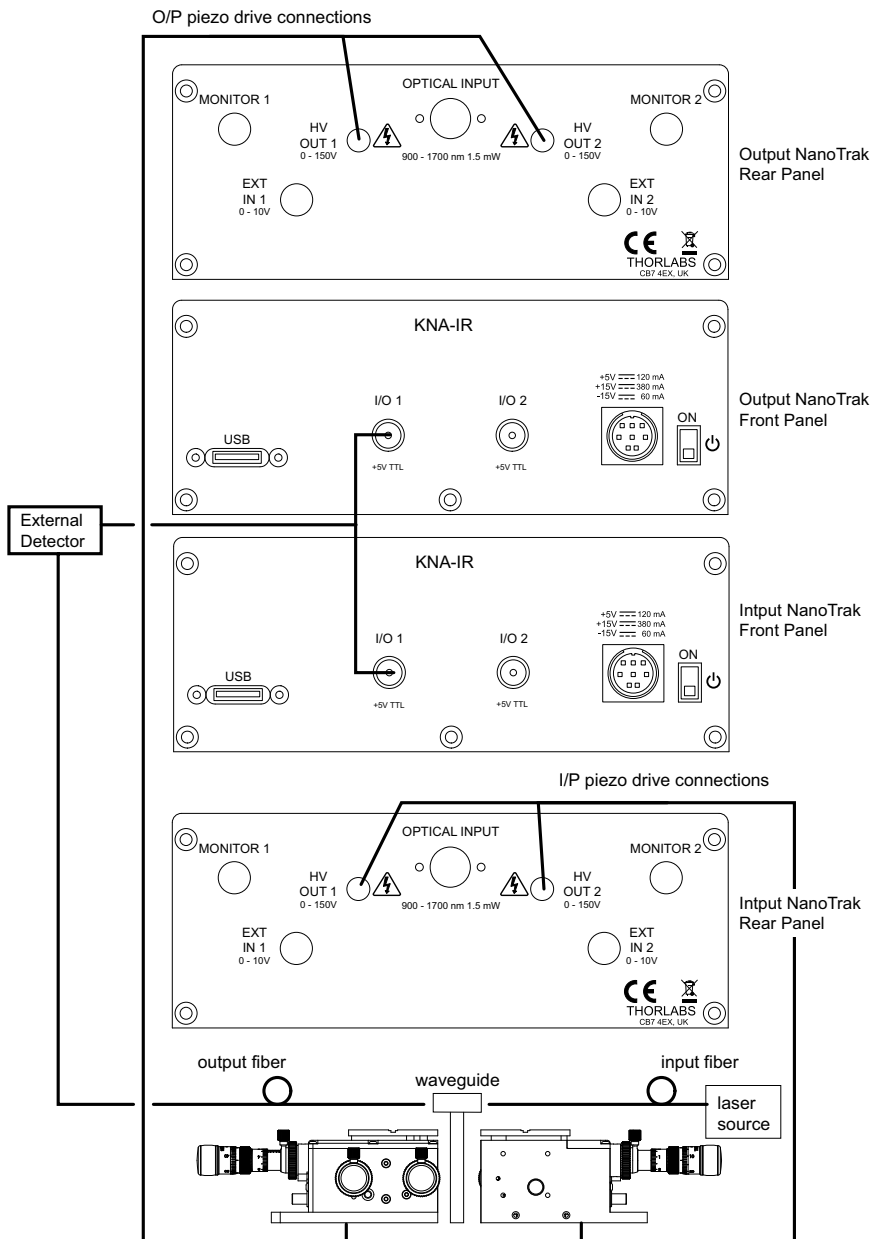


Fig. 5.8 Dual NanoTrak connections

5.6 Preventive Maintenance



Warning: Risk of Electrical Shock

The equipment contains no user servicable parts. There is a risk of severe electrical shock if the equipment is operated with the covers removed. Only personnel authorized by Thorlabs Ltd. and trained in the maintenance of this equipment should remove its covers or attempt any repairs or adjustments. Maintenance is limited to safety testing and cleaning as described in the following sections.

5.6.1 Cleaning

**Warning: Risk of Electrical Shock**

Disconnect the power supply before cleaning the unit.

Never allow water to get inside the case.

Do not saturate the unit.

Do not use any type of abrasive pad, scouring powder or solvent, e.g. alcohol or benzene.

The fascia may be cleaned with a soft cloth, lightly dampened with water or a mild detergent.

5.7 Troubleshooting

The signal level is too low

Ensure that the INPUT is set to optical.

The signal is not zero when set to EXTERNAL input

Apply a signal from a low impedance source (50Ω) the KNA has an internal pull up resistor used for the triggers if the input is in analogue mode an left floating. A low voltage might be present.

Unit not tracking

Signal too low.

Either one of the channel is in latch mode.

Check if the output are enabled (restore factory settings disables also the outputs).

Tracking circle smaller than programmed

Check the tracking frequency compared to the output current for the stage capacitance.

Check voltage range (it could be 75 instead of 150 V if 150 V is required).

The unit gets warm

The unit might warm up to 40-45 degrees. It is normal while the unit is ON.

Output is unstable

Check the fibers.

Perform an XY scan to ensure the alignment is being performed on the main power peak.

Check laser source.

Outputs are drifting

Check the latch mode (if no feedback is applied to the inputs the unit will drift).

Check PID settings of the latch modes if latch mode is needed.

Check the channels have not been swapped.

Although the green 'TRACKING' LED is on, the circle appears to wander across the display screen.

Increase the size of the scan circle diameter.

Increase the gain.

Adjust the phase offset.

Check the connections (see Section 3.3.4.). Check, using a dial gauge, that the stage moves in the horizontal and vertical axes (perpendicular to the fiber axis) when the manual control knobs on the Piezoelectric Controller GUI are adjusted.

An important point is that the 'TRACKING' LED is activated simply by an optical power threshold. If the power meter is set to a range that is too sensitive, it can be activated by noise. Increase the range, or adjust the micrometers to increase the optical power.

Given the answers above, how can I verify that the NanoTrak is really tracking?

If you make a small adjustment to one of the Micrometers, the circle will move slightly as the NanoTrak adjusts its drive outputs to track the maximum.

Does the circle have to be precisely in the center of the display?

No, the NanoTrak can track correctly as long as the circle is not at the edge of the display.

The optical power transmitted from fiber to fiber is much less than I expected.

Check that the ends of the fibers are well cleaved and clean.

Appendix A Power Connector Pin Out Details

A.1 POWER Connector

A.1.1 Pin Identification

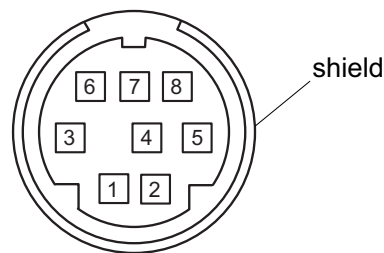
Thorlabs recommends that the NanoTrak K-Cube is operated with Thorlabs power supply TPS002, as it was specifically designed for use with this product. However, to enable customers to use the cube in installations where a $\pm 15V$ and 5V power is already available, the unit can be operated with a different external power supply, such as a bench or lab supply.

In this case however, extreme care must be taken to ensure that it meets the specifications and is connected to the cube correctly. Out of tolerance supply voltages or incorrect connection, applied even momentarily, can result in the sensitive electronic inside the cube getting damaged, invalidating warranty.

The K-Cube uses a standard “mini-DIN” type of input connector, the corresponding plug is available from most standard electronics suppliers.

The picture below shows the mini-DIN socket as viewed by looking at the rear panel of the cube. The pin numbering follows the standard for mini-DIN connectors

The pin functions are detailed in in Fig. A.1 .



Pin	Description	Pin	Description
1	+5V	6	Common Ground
2	+5V	7	Common Ground
3	-15V	8	Common Ground
4	+15V	Shield	Common Ground
5	+5V		

Fig. A.1 POWER Connector Pin Identification



Warning

When wiring the mini-DIN plug, ensure that all the ground pins are used and the shield is connected to common ground. This provides a level of protection against overvoltages due to loss of ground. A “loss of ground” condition can seriously damage the electronics inside the cube

Appendix B Specifications

B.1 Specifications

Optical Power Measurement	
Photo-Diode Type	KNA-IR: InGaAs KNA-VIS: Si FC/PC Connector
Detector Photocurrent	5 nA to 2.5 mA KNA-IR: 1.5 mW Saturation KNA-VIS: 4 mW Saturation
Wavelength	KNA-VIS: 320 to 1000 nm KNA-IR: 900 to 1700 nm
Optical Power Monitor (SMA)	Multiple Ranges
Signal Phase Compensation	-180° to 180°
Power Gradient Search	
Circle Scanning Frequency	4.4 to 87.5 Hz
Circle Position Range	<1% to >99% Max Piezo Extension
Circle Diameter Adjustment Modes	Automatic or Manual
Piezoelectric Input/Output	
HV OUT Connectors (SMC male)	Voltage Output: 0–150 VDC/Channel Output Current: 7.5 mA/Channel
MONITOR Outputs (SMA)	0–10 VDC
EXT IN Analog Inputs (SMA)	0–10 VDC
Other Input/Output:	
I/O 1 and I/O 2 Auxilliary Input/Output	I/O 1 Trigger Input/Output (0 to 5 V), or as External Input (0 to 2 V) I/O 2 Trigger Input/Output (0 to 5 V), or as External Output (0 to 2 V)
Input Power Requirements	
Voltage	+15 V (380 mA), -15 V (60 mA), +5 V (160 mA)
Power	<3 W
General	
USB Connection Speed	USB 1.1
Housing Dimensions (W x D x H)	121 x 60 x 47 mm (4.8" x 2.4" x 1.8")
Instrument Weight	0.45 kg (0.99 lb)

Appendix C Principles of Operation

C.1 The NanoTrak

C.1.1 Introduction

For simplicity, the following example refers to the alignment of two opposing butt-coupled single mode fibers, however the principles of operation are equally valid for the physical alignment of any two opposing optically coupled faces or indeed any two objects that can provide a feedback signal (voltage) that varies as a function of their alignment with respect to each other. .

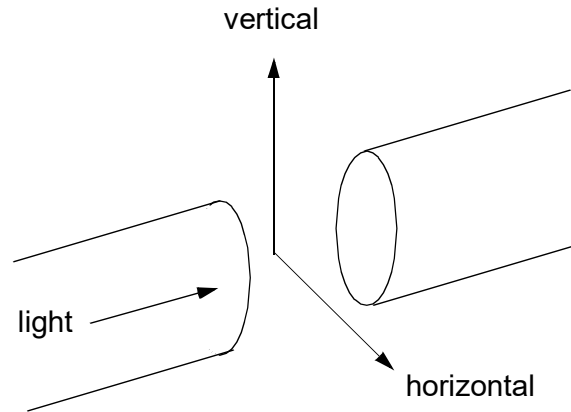


Fig. C.1 Alignment of optical fibers

In Fig. C.1, one of the fibers is fixed, the other is mounted on a piezo-actuated stage that moves the fiber in the horizontal and vertical axes. The NanoTrak must adjust the position of the moving fiber until the power transmitted between the two is maximized. Fig. C.2 shows a block diagram of the NanoTrak control loop. In many applications, a waveguide or similar device replaces one of the fibers, however this makes no difference to the principle of operation.

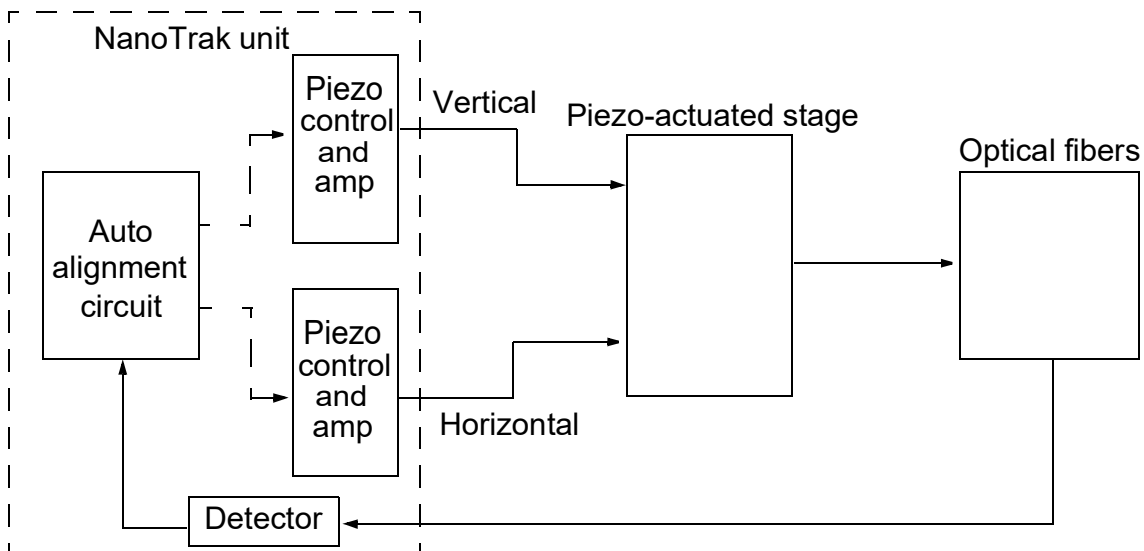


Fig. C.2 NanoTrak control loop

C.1.2 How the NanoTrak Maximizes Optical Power

To understand the principles involved in the alignment, consider the operation in a single axis. When two fibers are aligned, maximum power is transmitted between them, and if the fiber is moved a few microns to the left (Fig. C.3, position A), the power is reduced. Furthermore, oscillating the fiber by a few microns causes the detected power signal to assume an AC component whose amplitude is proportional to the amplitude of the mechanical oscillation (modulating signal).

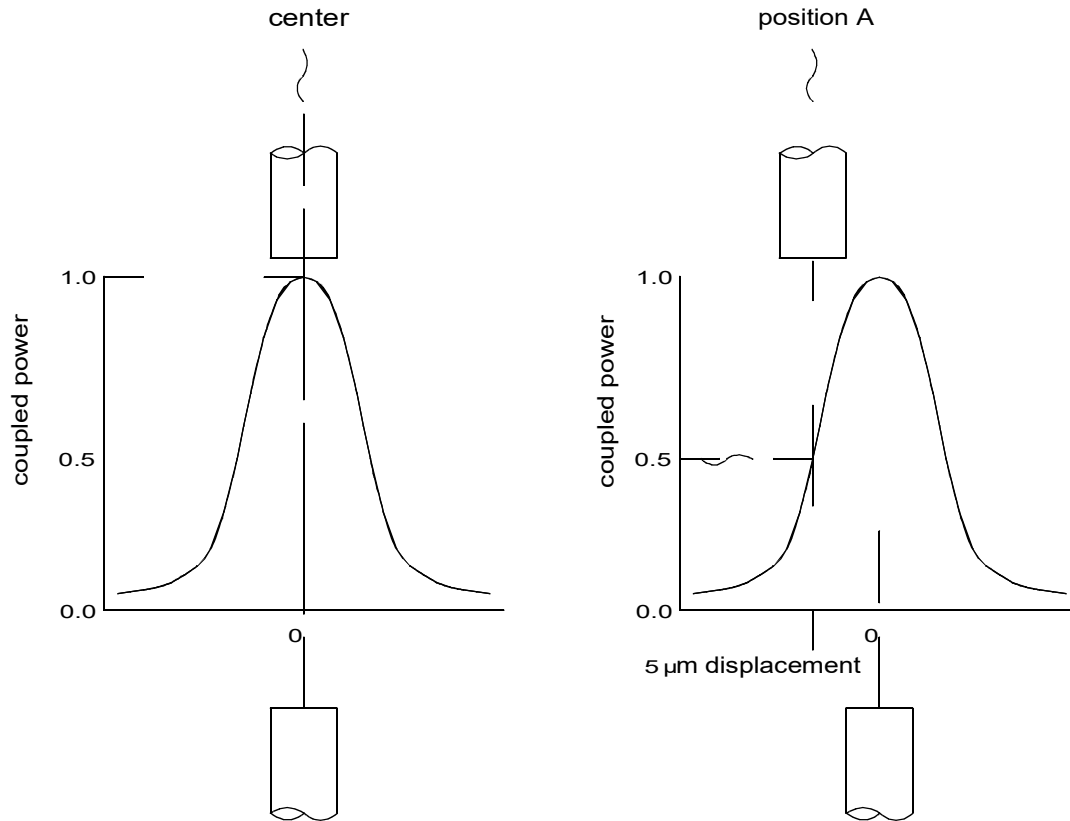


Fig. C.3 AC component of optical power

The received power signal contains a frequency component at the scanning frequency, and the phase of this (relative to the circle scan voltages) gives information on which direction to move.

When the circle is centred in the ideal position, the power signal contains no modulation at the scanning frequency. However, at position A, the signal has a phase difference with respect to the modulating signal. The power signal is Fourier analysed and the result of the computation is passed to an algorithm which drives the circle to the correct position.'

However, piezo transducers are unipolar and to achieve a positive and negative adjustment either side of center, the piezo must be at its center of travel when the error signal is zero. This is achieved by adding an offset voltage to the error signal.

Now, the range of the piezo is typically 20 to 30 μm , while the fiber is oscillated by 2 or 3 μm . Therefore, it can be seen, that by varying this offset voltage we can adjust the position at which the oscillation of the fiber takes place - see Fig. C.4 detail A.

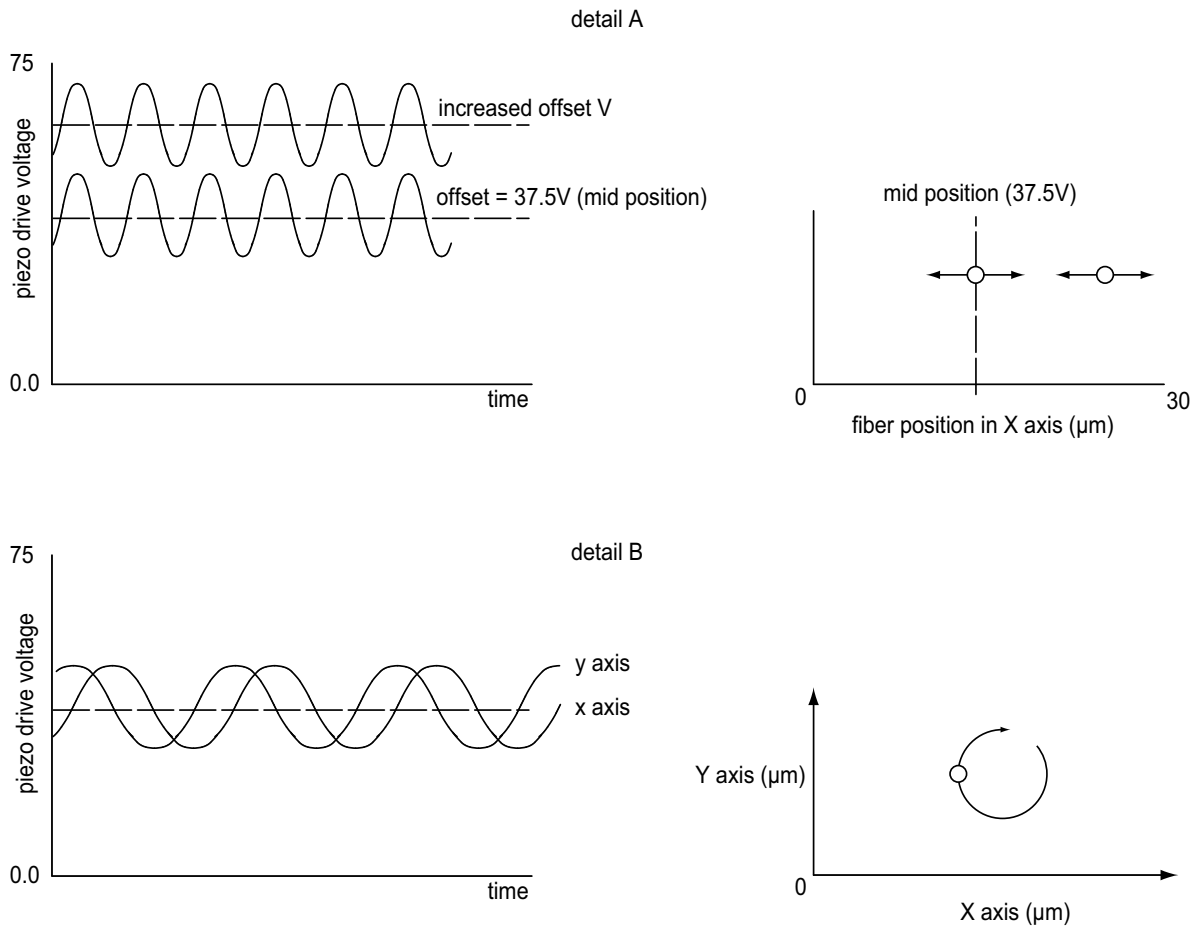


Fig. C.4 Offset voltage and fiber position

In reality, the fiber is oscillated both horizontally and vertically, with the modulating signal for Y phase shifted by 90° with respect to X - see Fig. C.4 detail B, which produces a circular oscillation. The detected signal is compared with both the horizontal and vertical phases of the modulating signal which results in both horizontal and vertical error signals.

As mentioned previously, the polarity of the error signals corresponds to the relative position of the two fibers and consequently, the signals can be used to drive the piezos until the fibers are aligned and the error voltages fall to zero.

Once the NanoTrak has found the position of maximum power, if one of the fibers is moved slightly (due to mechanical creepage or thermal drift), the NanoTrak detects the subsequent drop in power and corrects for the movement to maintain the maximum. This is called *tracking*.

C.1.3 Circle Size and Gain Control

Given that movement of two opposing fibers produces variations in the coupled power, the very act of automatically aligning the fibers to increase the coupled power may cause unwanted disturbances to the signal path.

Consider the optical profile in Fig. C.5. When the NanoTrak is tracking, the polarity of the resultant control voltage is determined by the position of the aligning fiber relative to the center line and the voltage amplitude is proportional to the amount of displacement from this center line.

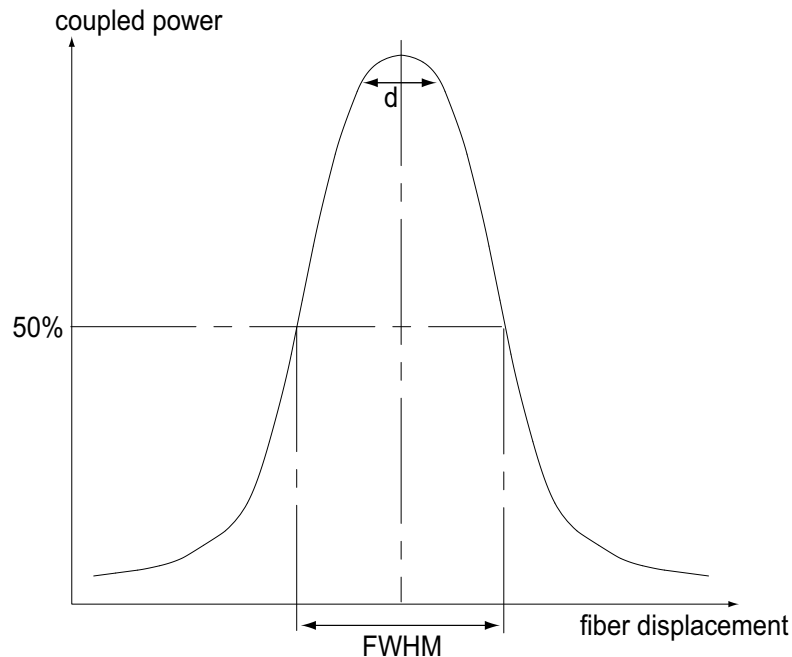


Fig. C.5 Circle diameter

If the scan circle diameter 'd' is such that the circle crosses the center line, the polarity of the control voltage is reversed and movement of the circle becomes erratic. The ideal circle size is dependant upon the shape and dimensions of the optical curve associated with a particular application, but should be between $1/10$ and $1/20$ FWHM (full width half maximum).

Under normal operation, the circle size should be reduced in proportion to the coupled signal, from a maximum of $3\ \mu\text{m}$ to a value of less than $50\ \text{nm}$. At the point of optimized alignment, this small modulating signal results in a small AC component, sufficient to maintain tracking but low enough to ensure that the resultant modulation does not interfere with the measurement being made.

The circle size can be set manually by entering a value in the Settings panel. Alternatively, if automatic LUT diameter adjustment mode is enabled, the system uses values in a LUT to modify circle diameter in relation to the input range currently selected.

This LUT diameter adjustment mode allows appropriate circle diameters to be applied on an application specific basis.

The loop gain can also effect system stability. If the gain is too high, the circle moves erratically, whereas too low a setting results in the circle 'floating' around the edge of the screen. Loop gain can be configured from the Controller GUI.

Both circle size and loop gain effect the system amplification. As a guide to manual settings, if the scan circle moves erratically round the screen, the amplification should be reduced, and conversely, if the scan circle movement is sluggish, the amplification should be increased. As with any phase locked control loop, it may be necessary to perform application-specific adjustments to optimize the speed of response and stability.

C.1.4 Phase Offset

Theoretically, if the NanoTrak were to read the power and respond by moving the fiber instantaneously, the power signal read in would be in phase with the modulating signal. In reality, the various electronic and electromechanical components (e.g. power meters, piezo actuators) within the control loop can introduce delays which means that the NanoTrak is always reacting to a power reading which was taken in the past. This, in turn, can cause a phase shift and, in extreme cases, can lead to instability.

A phase offset can be introduced to compensate for any phase shifts. In the system, a different phase offset can be specified for each axis of motion. This is particularly useful in those mechanical systems that exhibit different delays in different directions.

C.1.5 Latch, Track and Tracking modes


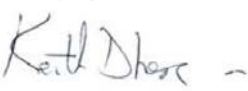

The purpose of the latch is to disable scanning and hold the drive outputs at the present position. With the latch released, the NanoTrak is in track mode. However, to minimise the risk of detecting a false peak, tracking should be activated only after a threshold power sufficiently above the background noise level has been located. See the table below for details of the three modes of operation.

Mode	Description	Button LED	Tracking indicator
Latch	Drive outputs held in constant position	Latch ON	OFF
Track mode, not yet tracking	The drive outputs wander and the circle drifts around the display	Track ON	OFF (i.e. below threshold power)
Track mode and tracking	The drive outputs seek and maintain maximum power settings	Track ON	ON (i.e. above threshold power)

Appendix D Regulatory

D.1 Declarations Of Conformity

D.1.1 For Customers in Europe

 THORLABS www.thorlabs.com	
EU Declaration of Conformity	
<i>in accordance with EN ISO 17050-1:2010</i>	
We:	Thorlabs Ltd.
Of:	1 St. Thomas Place, Ely, CB7 4EX, United Kingdom
<i>in accordance with the following Directive(s):</i>	
2014/35/EU	Low Voltage Directive (LVD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)
<i>hereby declare that:</i>	
Model:	KNA-IR and KNA-VIS
Equipment:	K-Cube NanoTrak Controller
<i>is in conformity with the applicable requirements of the following documents:</i>	
EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use. 2010
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements 2013
<i>and which, issued under the sole responsibility of Thorlabs, is in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:</i>	
does not contain substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive	
<i>I hereby declare that the equipment named has been designed to comply with the relevant sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.</i>	
Signed:	On: 18 July 2018
	
Name:	Keith Dhese
Position:	General Manager
 EDC - KNA-IR and KNA-VIS -2018-07-18	

D.1.2 For Customers In The USA

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Changes or modifications not expressly approved by the company could void the user's authority to operate the equipment.

Chapter 5 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at www.thorlabs.com/contact for our most up-to-date contact information.



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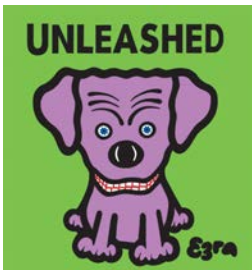
Thorlabs Vendas de Fotônicos Ltda.
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Thorlabs verifies our compliance with the WEEE (Waste Electrical and Electronic Equipment) directive of the European Community and the corresponding national laws. Accordingly, all end users in the EC may return "end of life" Annex I category electrical and electronic equipment sold after August 13, 2005 to Thorlabs, without incurring disposal charges. Eligible units are marked with the crossed out "wheelie bin" logo (see right), were sold to and are currently owned by a company or institute within the EC, and are not disassembled or contaminated. Contact Thorlabs for more information. Waste treatment is your own responsibility. "End of life" units must be returned to Thorlabs or handed to a company specializing in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.





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