

MNA601/IR NanoTrak[®] Control Module

APT User Guide



Original Instructions

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Chapter 1 Overview

1.1 APT Rack System Description

1.1.1 Introduction

Thorlabs has an extensive range of one-, two- and three-axis controllers for stepper motor and piezo actuator control. Increasingly, production of optoelectronic components requires fully automated or semiautomated control of a large number of mechanical stages. In such applications, it is often more convenient to use a modular system of controllers to drive a modular system.

The Thorlabs Modular Motion Control System has been developed to meet the challenges of the modern optoelectronic production environment and provides unsurpassed ease of installation, reconfiguration, flexibility and upgradability.

The MMR601 modular rack provides a highly functional 12 channel platform within the 'footprint' of a 4U high, 19" wide enclosure. With a unified power supply and a USB communications interface, the APT rack system is easily incorporated into larger custom applications.

1.1.2 Building Larger Scale Systems

The unrestricted configuration flexibility offered by the APT rack allows any combination of the 2-channel APT stepper motor controller, piezoelectric driver and NanoTrak[®] control modules to be fitted for specific nanopositioning and alignment applications. For example, a system configured to operate our APT606 6-axis nanopositioning stage, which has six stepper motors and six piezoelectric actuators with displacement sensors, would require 12 channels of motion control. Using three stepper motor modules, each with two channels, provides the motor control; using two piezoelectric controller modules and one NanoTrak controller module would power all 6 of the piezoelectric actuators while also taking advantage of the position sensors. Additionally, the NanoTrak module provides the full range of features offered by a fully operational auto-alignment system. All this functionality fits into the single MMR601 chassis that measures just 4U in height.

Please see the documentation supplied with the various module products for further details.

1.1.3 Ease of Use

The rack system architecture, hardware and software has been skilfully engineered to provide an efficient and effective solution to complex high channel count applications.

The APT rack presents a clean, uncluttered front panel, with six rear mounting bays for the plug-in modules. The backplane of the rack connects all modules and the control PC via a standard USB bus. This arrangement greatly simplifies the cable management issues that arise as the number of channels expands.

A flexible and energy efficient integral power supply powers all of the modules allowing for an adaptable, "mix-and-match" choice of module type, location and combination. These features greatly enhance ease-of-use, and provide an unparalleled flexibility for future system upgrades or reconfigurations. Each module is equipped with an on-board DSP embedded processor; as modules (channels of operation) are added, processing power is also added, hence the system is able to maintain maximum operating efficiency even when fully loaded.

Due to the inherent architecture of the system, additional racks can be added to the USB bus as required, thus allowing multiple, fully automated 6-axis positioning stages to be combined into a single unified motion control system.

The PC based software that is used to drive the MMR601 system operates from the same kernel of ActiveX multithreaded server code and associated suite of high level user applications used to drive our range of APT stand-alone bench top controllers. This makes it possible to offer effortless code-porting and concurrent control of bench top and rack controllers.

The APT software is rigorously engineered using modern object oriented techniques, ensuring programming environment independence and compatibility with a large number of third party development tools. All key high level commands, settings and system parameters are exposed through a set of ActiveX Drivers. These exposed objects allow the modular electronics system to be 'driven' from applications written by the user without the need to understand or alter the core system software.

In addition, ActiveX technology is language independent, allowing custom application development to be undertaken using any language or development system that supports ActiveX.

1.2 Software

1.2.1 Background

A common requirement in many optoelectronic alignment and characterization applications concerns the implementation of automated positioning sequences. Typically, such positioning sequences require a series of discrete movements and measurements to implement an overall solution

The mechanical stage options and drive electronics offered by Thorlabs are ideally suited to performing all of these individual steps in a variety of different ways.

The key to the APT range of controllers (and associated mechanical products) concerns the ease and speed with which complete automated alignment systems can be engineered at the software level. All controllers in the APT range are equipped

with USB connectivity. The 'multi-drop' USB bus allows multiple APT units to be connected to a single controller PC using simple USB hubs and cables.

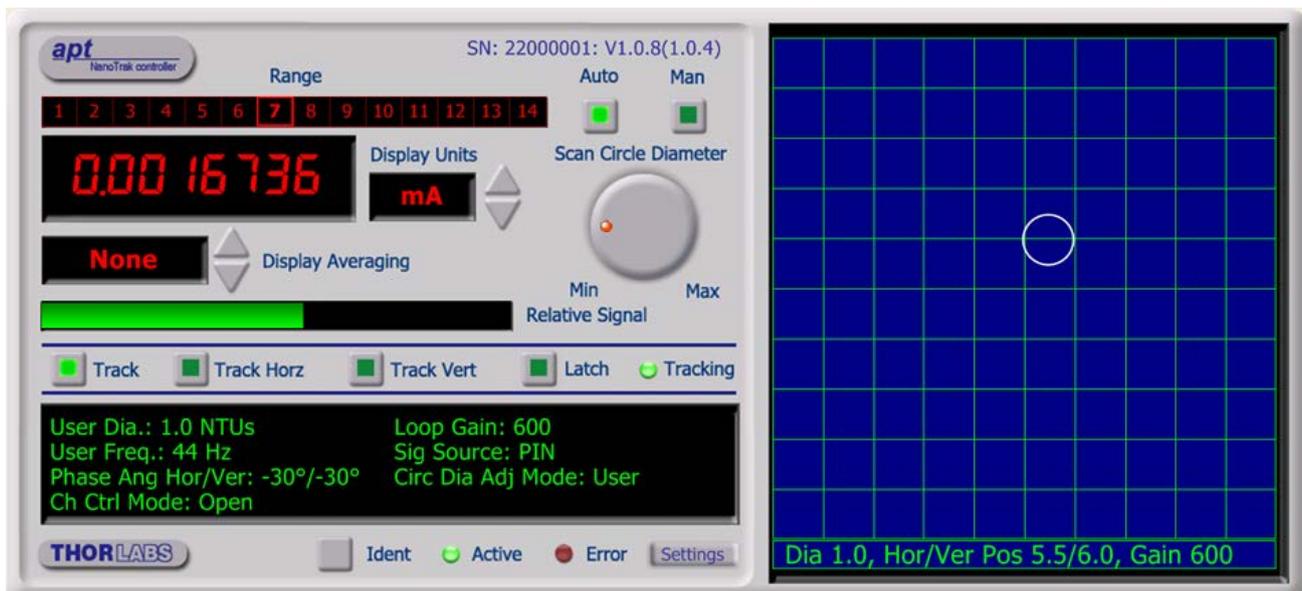
The USB connection flexibility offered by the APT controllers is matched by the associated product software. All APT controllers are shipped with a sophisticated multithreaded ActiveX based software control suite. This suite comprises the main ActiveX based APT Server with a number of utilities including APTUser and APTConfig. APT Server is the main software 'engine' that runs on the host PC to provide all necessary APT services such as generation of sophisticated graphical instrument panels, multiple unit USB communications and multithreaded execution to enhance system operation and prevent GUI deadlock. Rather than a single monolithic entity, the APT Server is actually an interoperating collection of ActiveX Controls (or simply Controls) together with associated support files and libraries. These ActiveX Controls, developed using leading edge object oriented coding techniques, are the key to the powerful, flexible and yet extremely easy to use APT control software.

1.2.2 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. 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, HPVVEE, Matlab, VB.NET, C#.NET and, via VBA, Microsoft Office applications such as Excel and Word.

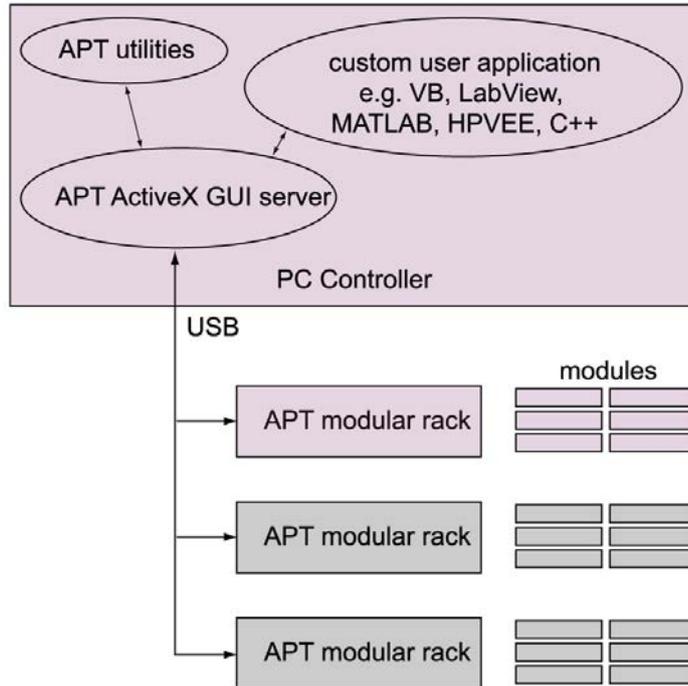
Consider the ActiveX Control supplied for the APT NanoTrak control module.



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 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.

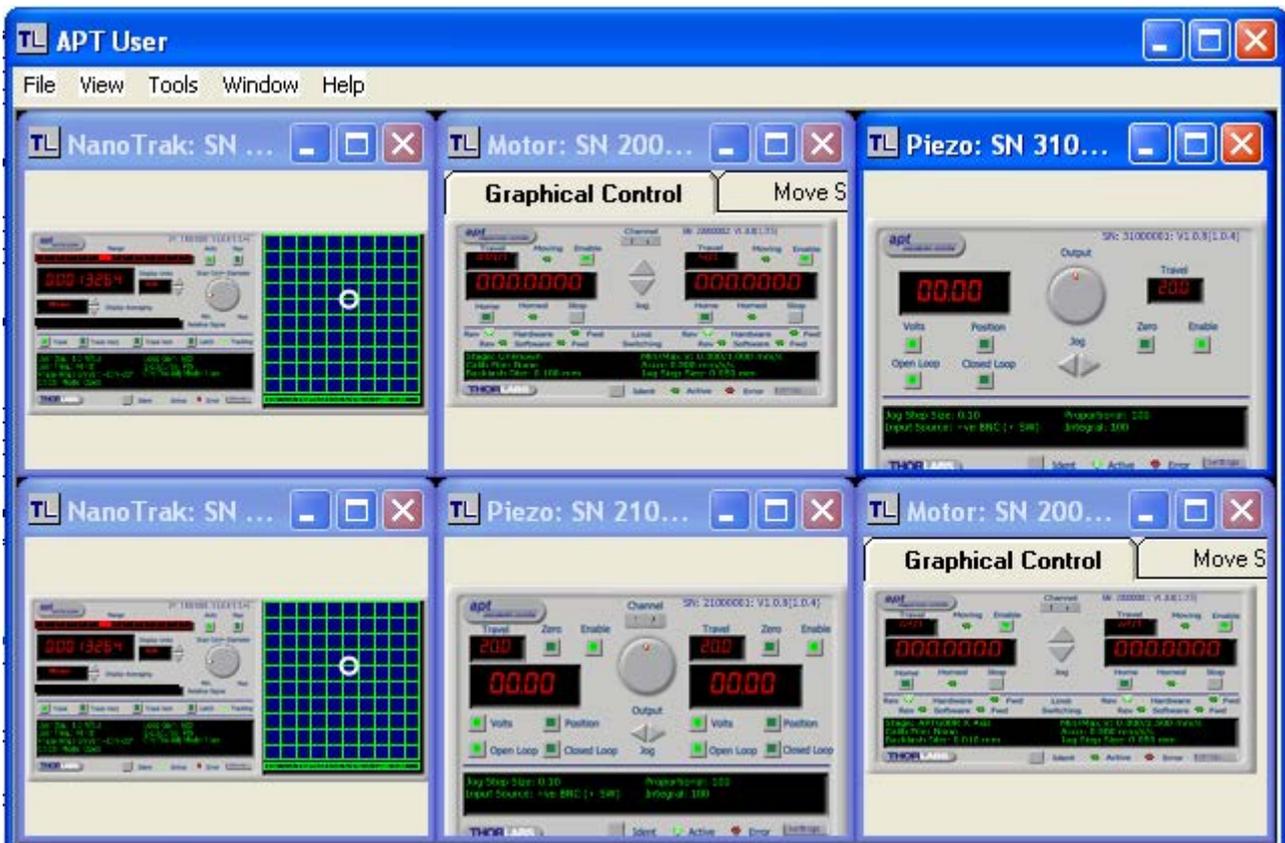
The APT ActiveX Controls collection provides a rich set of graphical user panels and programmable interfaces allowing users and client application developers to interact seamlessly with the APT hardware. Each of the APT controller modules has an associated ActiveX Control and these are described fully in system online help or the handbooks associated with the controllers. In addition to the main ActiveX Server, a number of other utilities are supplied with the APT system, most notably

APTUser and APTConfig. Note that these utilities themselves take advantage of and are built on top of the powerful functionality provided by the APT ActiveX Server (as illustrated in the system architecture diagram below).



1.2.3 APT User.exe

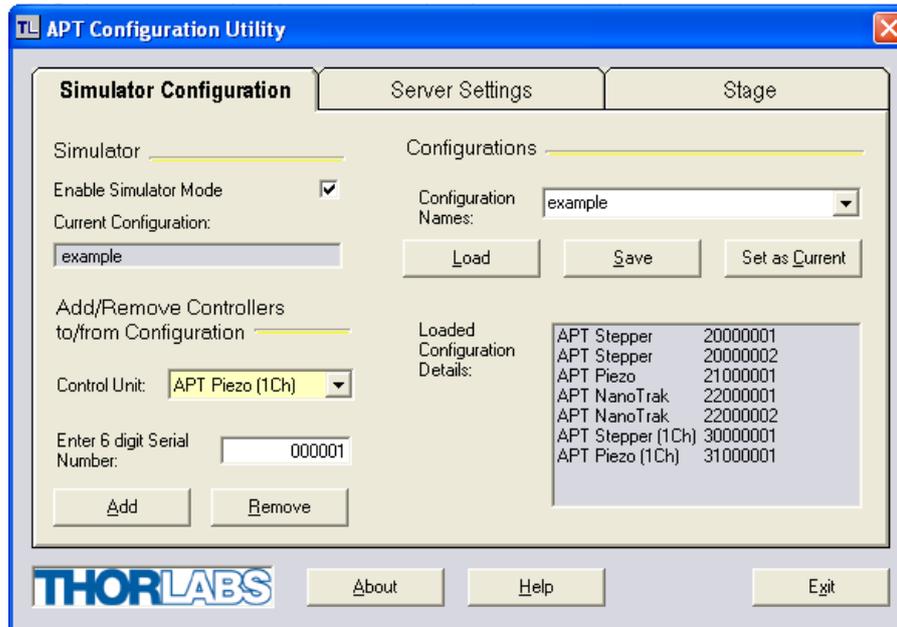
The APTUser application allows the user to interact with a number of APT hardware control units connected to the host PC. This program displays multiple graphical instrument panels to allow multiple APT units to be controlled simultaneously.



All basic operating parameters can be altered and, similarly, all operations (such as motor moves) can be initiated. 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 customise and automate usage of the APT modules (e.g. to implement an alignment algorithm), this application illustrates clearly how the rich functionality provided by the APT ActiveX Controls are used by a client application.

1.2.4 APT Config Utility

There are many system parameters and configuration settings associated with the operation of the APT Server (ActiveX Controls). Most can be directly accessed using the various graphical panels and their associated programmable interfaces. However there are several system wide settings that can be made 'off-line' before running the APT software. These settings have global effect; such as switching between simulator and real operating mode, associating mechanical stages to specific motor actuators 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.

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.

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 Kinesis 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 Description

3.1 NanoTrak Autoalignment Description

3.1.1 Introduction

The APT Modular NanoTrak Controller is available for use with the Thorlabs APT Modular Motion Control System and represents the latest development in automated optical alignment technology. It combines an intelligent active-feedback alignment control system and a two channel piezoelectric controller into a single plug-in unit. As part of the APT series, this autoalignment system represents the latest developments in automated optical alignment technologies. This system is a basic building block from which advanced alignment systems can be quickly configured. It can be fully integrated into a system that is comprised of a selection of our modules; piezoelectric controllers, stepper motor controllers, and this NanoTrak autoalignment module. Although used primarily for aligning optical fibers and integrated optical devices, the NanoTrak is ideal for automating just about any labor intensive alignment task at the nanometer regime.

3.1.2 NanoTrak System Architecture

The modular NanoTrak unit comprises a PIN photodiode and transimpedance amplifier, an adjustable (proportional and integral) servo control loop, and a dual channel HV amplifier output circuit for driving two piezo actuators connected to a positioning stage. The NanoTrak control loop is tasked with maximizing the feedback signal by adjusting the HV amplifier outputs in order to physically move a portion of the optical assembly that is being optimized. It does this by superimposing a small user adjustable sinusoidal voltage on the HV amplifier outputs. The sinusoidal modulation is phase shifted by 90° between the two channels. If the two piezo actuators are orthogonal to each other, the resulting motion will be circular.

By sampling the feedback signal (typically the optical power level) around the circular trajectory it is possible for the algorithms on the NanoTrak module to determine a signal gradient. The output HV amplifier offset voltages - DC signal levels - are then adjusted to move the circle, and hence the device under alignment, in the direction of increasing signal. When the device is centered on the signal peak, the signal gradient around the circle of motion is zero and the NanoTrak has achieved optimal coupling of the device under its control. At this point the NanoTrak dithering can be suspended (outputs latched) for static alignment requirements or dithering continued at smaller amplitudes for active continuous alignment in applications that suffer from drift - see Chapter E for further information of the NanoTrak principle of operation.

3.1.3 Highly Adaptable Settings

There is an infinite variety of optical device alignment scenarios, each with potentially different optical and physical characteristics; half widths, coupled peak powers, misalignment power response, and mechanical phase lags. Given the range of applications, it is important that NanoTrak be easily 'tuned' for a specific alignment task. In order to achieve this adaptability, the NanoTrak controllers' operation is fully configurable with many of the operational parameters of the system accessible through a series of easy to use software panels. This "parameterization" of the key settings with predetermined defaults and accessibility from the associated graphical interface panels makes the system highly adaptable.

3.1.4 Ease of Use

For convenience and to further enhance the ease of use, adjustment of many key parameters is possible through direct interaction with a software generated graphical panel that has a mixture of analog and digital controls. For example, the Circle Diameter previously defined can be adjusted by using the mouse to rotate a simple computer generated knob. Note that all such settings and parameters are also accessible through the ActiveX programmable interfaces for automated alignment sequences. See Section 1.2. for a description of the APT system software.

3.1.5 Rear Panel Connections

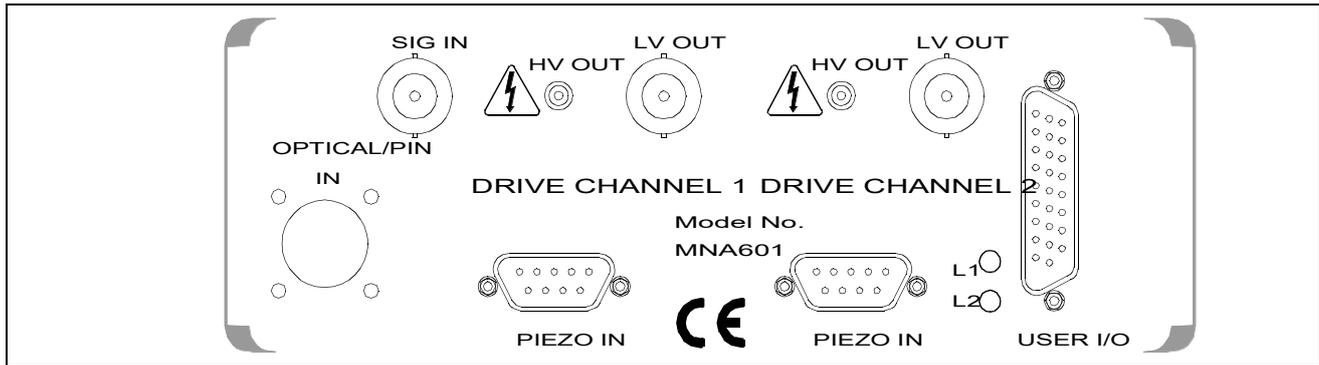


Fig. 3.1 Rear panel connections

OPTICAL/PIN I/P - *SMB connector* – used to receive a signal from a PIN diode, as incorporated in external detector heads.

FC/PC connector – for use with detectors NTA007 and NTA009. Incorporates an internal detector and accepts a connectorized fiber.

SIG IN (BNC connector) – 0 to 10V, 100k Ω load. Used to receive a signal of optical power from an external power meter. Can be set to $\pm 1V$, $\pm 2V$, $\pm 5V$ or $\pm 10V$ full scale in the Settings panel (see Section 4.5.2.) or by calling the NanoTrak SetInputSrc method (see *the helpfile supplied with the APT Server*).

DRIVE CHANNEL 1

HV OUT (SMC connector) – 0 to 75V, 0 to 500mA. Provides the drive signal to the piezo actuator.

LV OUT (BNC connector) – 0 to +10V. This output is mirrors HV OUT, 10V being equivalent to 75V on the HV outputs, and can be connected to an oscilloscope to enable the drive signal of the piezo actuator to be monitored.

PIEZO IN (9-pin D type connector) – For use with piezo actuators with feedback capability. Two types of feedback signal are supported, *AC Strain Gauge* and *DC 0-10V*. The pin function is dependent on the feedback option, set in the Settings panel, see Section D.1.2. and Section 5.2.3.

DRIVE CHANNEL 2 – as DRIVE CHANNEL 1.

L1 (Green) - Lit when power is applied to the unit.

L2 (Red) - Indicates a fault condition exists.

USER I/O (26-pin D type connector) - The User I/O connector exposes a number of internal electrical signals. For convenience, a number of logic inputs and outputs are included, thereby negating the need for extra PC based IO hardware. Using the APT Server software, these user programmable logic lines can be deployed in applications requiring control of external devices such as relays, light sources and other auxiliary equipment, or when operating a dual NanoTrak application - see Section 5.2.2. for pin-out details.

3.1.6 Detector Heads and Cables

The OPTICAL/PIN I/P connector on the rear panel of the NanoTrak controller has been designed to increase the interchangeability of the optical input source. A range of connectors are available which simply plug into the connector on the rear panel.

The MNA601/IR NanoTrak is supplied with an Infra Red InGaAs photodiode, and a standard SMB connector for use with external detector heads which incorporate a PIN (p-type/intrinsic/n-type) diode.

A visible spectrum Si photodiode (NTA009) is available separately.

Chapter 4 Set Up and Operation

4.1 Introduction

The functionality required for a client application to control a number of NanoTrak units is provided by the NanoTrak Control Object within the APT server, with manual operation being facilitated via a GUI panel (see Section 4.5.1.). Instances of this ActiveX control can be dragged from the toolbox in the development software. Alternatively, the APT User utility allows multiple graphical instrument panels to be displayed so that multiple APT units can be controlled. All basic operating parameters can be set through this program, and all basic operations (such as setting circle diameter) can be initiated.

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 APT NanoTrak controller can be programmed as part of an automated alignment application.

Note

Before using the NanoTrak, ensure that the fibers can be aligned manually using the actuators on the positioning stage, and that the expected level of power can be transmitted between them. Set the NanoTrak to Latch and the range control to Auto, and observe the bar graphs on the front panel for an indication of power.

If the positioning stage incorporates stepper motor actuators, ensure that the motors are disabled via the stepper motor controller GUI panel before performing any manual adjustment.

4.2 Software Installation and Upgrade

4.2.1 Software Installation



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/Downloads at www.thorlabs.com and download the APT software.
- 2) Run the .exe file and follow the on-screen instructions.

4.3 System Setup

- 1) Install the APT software as detailed in Section 4.2.
- 2) Install the electronic hardware and connect the controller to the relevant axes of the associated stages (see Chapter 5).
- 3) Run the APTUser utility and check that the unit powers up.

Note

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 to application program development and testing. Any number of 'virtual' control units are combined to build a model of the real system, which can then be used to test the application software offline.

- 4) If using real hardware, ensure that Simulator Mode is disabled. If using a simulated setup, enable Simulator Mode and set up a 'Simulated Configuration' - see the *APTConfig* helpfile for detailed instructions.
- 5) Begin using the APT hardware.

4.4 Assigning a Serial Number

Every hardware unit is factory programmed with a unique 8-digit serial number. This serial number is key to operation of the APT Server software and is used by the Server to enumerate and communicate independently with multiple hardware units connected on the same USB bus.

Before an ActiveX control can communicate with the associated hardware unit, the relevant serial number must be allocated to the control instance. This is performed automatically when using the APT User utility. For custom application software it must be achieved by calling the HWSerialNum property.

4.5 Manual Operation - NanoTrak

4.5.1 Description of GUI Panel Controls



Fig. 4.1 NanoTrak Software GUI

The software drivers consist of several 'Objects', which in turn contain 'Methods' and 'Properties'. The 'NanoTrak' object contains the methods which facilitate the programmed operation of the unit.

The methods are used to perform such tasks as setting the circle diameter and position, returning the value of optical power input, setting scan frequency and phase offset, and setting Latch or Track mode.

A brief overview of the methods and properties of the NanoTrak object can be found in Chapter C. More detailed information, can be found in the *APTServer Helpfile*.

Programmed operation of the NanoTrak controller allows a wider range of functions to be used than operation from the GUI panel alone. Other units such as the APT Stepper Motor controller can also be controlled with the NanoTrak.

Note

The serial number of the APT unit associated with the ActiveX control instance (allocated using the HWSerialNum property), the APT server version number, and the version number (in brackets) of the embedded software running on the APT unit, are 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 3 nanoamps (range 1) to 10milliamps (range 14) (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.

Auto and Man - push button control used to toggle between auto and manual ranging. The LED in the button is lit when selected.

Digital Display - shows the feedback signal level being measured.

Display Units - show the measurement units associated with the display or returned by methods that return feedback signal readings.

If a PIN (TIA) input signal is connected (input source is set to TIA mode using the *SetInputSrc* method), the display can be configured to display mA, mW or dB.

If 'mA' is selected, readings are displayed or returned as 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 SetUnitsMode method.

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 BNC input is connected (input source is set to a BNC mode using the SetInputSrc method), 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 BNC 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 BNC 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 SetInputSrc method (or 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 1V signal into a 2V input range BNC will display a value of 10.

Display Averaging - 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 ActiveX methods.

To change the setting, click the arrow buttons.

Scan 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' window. Note. Use of this control will automatically switch the circle diameter adjustment mode to 'Manual'.

Relative SignalPower - The max power located in the alignment. Bar display showing a convenient visual indication of the feedback signal level. When the input source is set to TIA (PIN), the bar display indicates the power level with respect to the currently applied range. E.g. if the TIA range is 1micro, then a bar displaying half length equates to a power level of 0.5micro. When the input source is set to BNC (voltage), then bar display indicates the voltage being measured. E.g. for an input voltage range of 2volts, a bar displaying half length equates to 1volt 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.

Track Horz - 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.

Track Vert - 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.

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.

Tracking indicator - lit when the NanoTrak is tracking and measuring feedback signal levels above a software threshold set using the SetTrakThreshold method or the Settings button. 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 tracking indicator does not apply when the input source is set to BNC (voltage) input.

CRT 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 10 NanoTrak (NT) units, each division being 1/10th of the max piezo travel, (e.g. for a 20µm piezo travel, 1 NT unit = 2µm).

The CRT also displays the settings currently applied for the following parameters:

Dia - the circle diameter (in NT units)

Hor/Ver Pos - the horizontal and vertical coordinates of the circle position

Gain - the gain setting of the NanoTrak control loop.

Settings display - 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 (and in some cases, displayed on the CRT).

User Dia - displays the circle diameter (in NT units). The circle diameter can be set either by adjusting the manual control knob or by calling the *SetCircDia* method.

Note

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

User Freq - displays the scanning frequency (in Hz). The scanning frequency can be set either by entering a value in the 'Settings' panel, or by calling the 'SetCircFreq' method.

Phase Ang Hor/Ver - 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 or by calling the *SetPhaseComp* method. Note. If the phase compensation adjustment mode is set to 'Auto', the actual phase offset may be different to the diameter displayed. (see Section E.1.4. for further information).

Ch Ctrl Mode - indicates the open or closed loop status of the output HV amp channels. In closed loop mode the output channels are relying on a feedback signal (i.e. from a piezo actuator based strain guage) in order to operate to a setpoint determined by the NanoTrak algorithm. This is not an advised mode of operation when Nanotraking, where it is more usual to operate the HV output channels in open loop mode.

Loop Gain - displays the gain setting for the NanoTrak control loop. The gain can be set either by entering a value in the 'Settings' panel or by calling the *SetLoopGain* method.

Sig Source - displays the type of input source connected. The input source is set by entering a value in the Settings panel or by calling the *SetInputSrc* method).

Circ Dia Adj Mode - displays the mode of circle diameter adjustment as follows:

- | | |
|------------------|---|
| <i>SW (user)</i> | Diameter adjusted through software |
| <i>LUT</i> | Diameter adjusted via Look Up Table
(see <i>SetCircDiaLUTVal</i> and <i>SetCircDiaMode</i> methods). |

Settings button - Displays the 'Settings' panel, which allows the NanoTrak's operating parameters to be entered - see Section 4.5.2.

Ident - when this button is pressed, the channel LEDs on the I/O panel of the associated hardware module will flash for a short period.

Active - lit when the unit is operating normally and no error condition exists.

Error - lit when one of the following fault condition occurs:

- 1) One or more power supply voltages are out of range.
- 2) Channel 1 or channel 2 has closed loop mode selected but the associated piezo is disconnected.

4.5.2 NanoTrak Settings Window

When the 'Settings' button on the GUI panel is clicked, the 'Settings' window is displayed. This panel allows data such scan circle frequency and diameter, and loop gain to be entered. The various parameters are described below.

Tracking tab

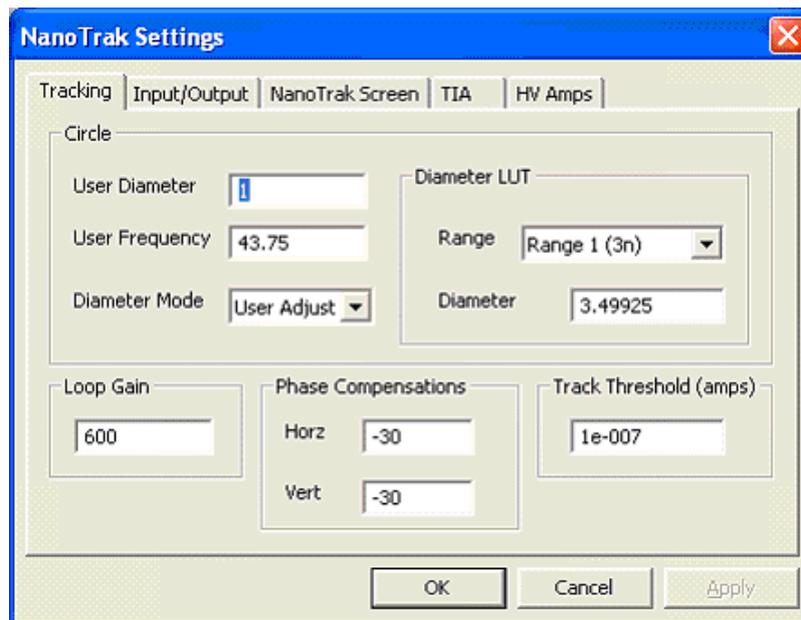


Fig. 4.2 NanoTrak Settings panel - Tracking Tab

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.

User Frequency - the frequency of the scanning circle. The circle scanning frequency lies in the range 15 to 200Hz. 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 4.6.3. 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 parameters 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 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 14, corresponding to 3nA to 10mA 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 behaviour 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.

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 physical 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.

Input/Output tab

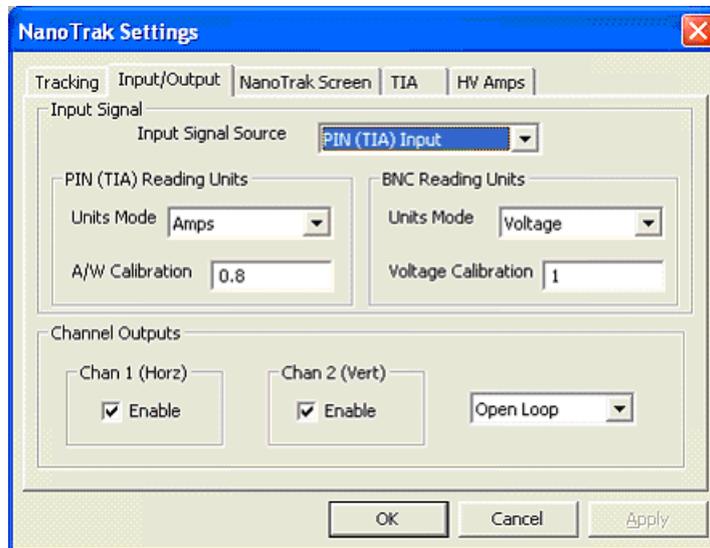


Fig. 4.3 NanoTrak Settings panel - Input/Output Tab

Input Signal

Input Signal Source - the input source can be set to PIN (TIA) or a range of BNC voltage inputs.

The PIN (TIA) Input option should be used when NanoTraking to optimise a PIN current feedback signal. The TIA (trans impedance amplifier) input source should be selected when using the rear panel Optical I/P connector or when an external detector head is connected to the optional SMB connector. This option uses the internal amplifier circuit and associated functionality (e.g. autoranging).

The BNC Input options should be used when NanoTraking to optimise a voltage feedback signal. Typically, these inputs are selected when using an external power meter 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 can be set to 1V, 2V 5V or 10V.

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.

BNC Reading Units

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

If *Voltage* is selected, readings are displayed or returned in Volts, i.e. the raw input signal to the BNC connector.

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

If *User Calib* 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 1V signal into a 2V input range BNC will display a value of 10.

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

Channel Outputs - these parameters allow the horizontal and vertical channels of the NanoTrak to be enabled/disabled.

Note

NanoTrak channels should not normally be disabled.

Open/Closed Loop - Typically, the NanoTrak is operated in Open Loop mode because the piezo amplifiers have a higher bandwidth operation in open loop, thereby ensuring best bandwidth performance. If the NanoTrak is latched, the piezo actuator position is best maintained if the drift is minimized. This is achieved by placing the piezo channels into Closed Loop mode.

When in closed-loop mode, position is maintained by a feedback signal from the piezo actuator strain gauge or by a DC feedback signal derived externally. **Note.** This is only possible when using actuators equipped with position sensing.

NanoTrak Screen tab

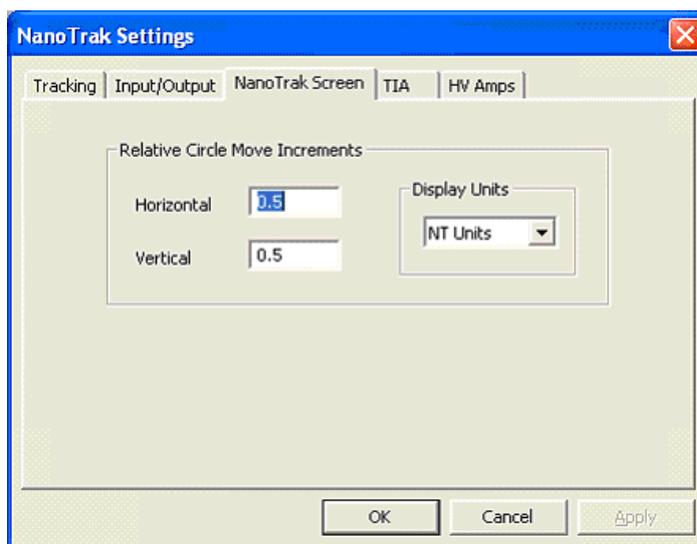


Fig. 4.4 NanoTrak Settings panel - NanoTrak Screen Tab

Sometimes, it may be useful to explore the area of interest by manually repositioning the two piezos driven by the NanoTrak. If desired, the NanoTrak circle can be positioned by using the mouse. 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 - When the circle is positioned by a mouse click, the incremental distance can be set to NT units or microns. If set to NT Units, the increments can be set from 0.01 to 2 NT units.

If set to microns, the limits are dependent upon the travel of the piezo actuator, e.g. for a 20 μ m piezo travel, 1 NT unit = 2 μ m, therefore the limits are 0.02 to 4 μ m.

Display Units - The display at the bottom of the NanoTrak screen shows the circle diameter and the horizontal and vertical co-ordinates of the circle position.



Fig. 4.5 NanoTrak screen - circle coordinates

This data can be set to display in microns or NanoTrak units.

Note

This setting affects only the NanoTrak screen and not the main 'Settings' display.

If 'Microns' is selected and no piezo actuators are connected, the system sets automatically the increment size to be the micron equivalent of 1 NT unit, e.g. for a 20µm piezo travel, the increment would be set to 2µm.

To indicate that 'Microns' is selected and no piezo is connected, the data displayed at the bottom of the NanoTrak screen is set to zero.



Fig. 4.6 NanoTrak screen - circle coordinates

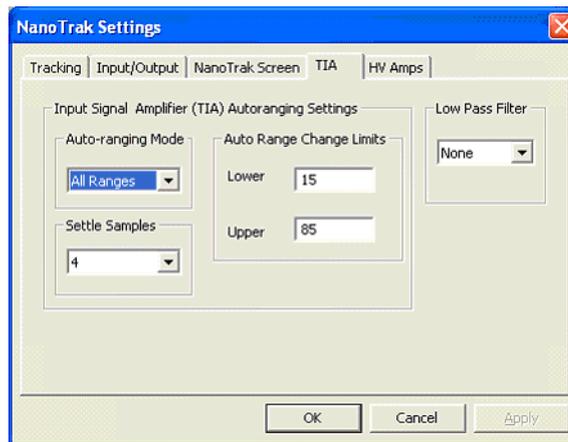
TIA tab

Fig. 4.7 NanoTrak Settings panel - TIA tab

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

Input Signal Amplifier (TIA) Autoranging Settings

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 adjusts continually 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 SettleSamples values improve the signal to noise ratio when dealing with noisy feedback signals. However, higher SettleSamples values also slow down the autoranging response. In a particular application, the SettleSamples 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'.

Low Pass Filter - This setting specifies the cut off frequency of the digital low pass (LP) filter applied to output readings of the internal amplifier (TIA) circuitry. If the readings displayed or returned are unstable, this setting can be used to remove any unwanted high frequency components and improve input signal stability.

NONE - Low pass filter inactive	10HZ - Cut off all signals above 10Hz
1HZ - Cut off all signals above 1Hz	30HZ - Cut off all signals above 30Hz
3HZ - Cut off all signals above 3Hz	100HZ - Cut off all signals above 100Hz

Note

This low pass filter setting is different to the low pass filter specified using the HV Amps tab or the SetAmpOutputParams method.

HV Amps Tab

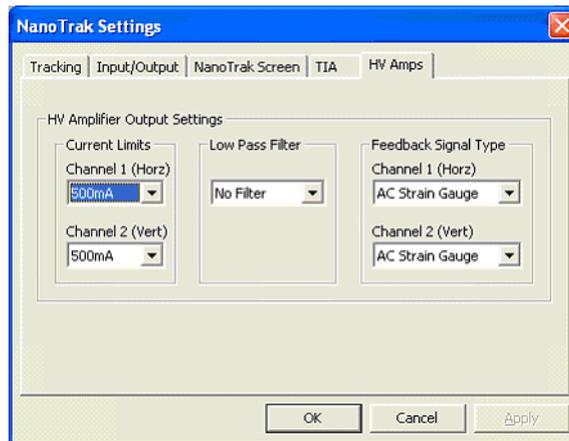


Fig. 4.8 NanoTrak Settings panel - HV Amps tab

This panel is used to set the output characteristics of the HV amplifier channels fitted to the NanoTrak unit. Both low pass filtering and current control settings can be made to tailor the piezo output drive to a particular application.

Current Limits - This parameter sets the maximum current output of the HV amplifier:

- 100MA – Current output (piezo drive signal) limited at 100mA
- 250MA – Current output (piezo drive signal) limited at 250mA
- 500MA – Current output (piezo drive signal) limited at 500mA

Low Pass Filter – This parameter sets the cut off frequency of the hardware low pass filter, applied to the HV amplifier output channels. It applies to both channels simultaneously.

- 10HZ - Cut off all signals above 10Hz
- 100HZ - Cut off all signals above 100Hz
- 5KHZ - Cut off all signals above 5KHz
- NONE - Low pass filter inactive

Note

This low pass filter setting is different to the low pass filter specified using the TIA screen (or the SetLPFilter method).

Feedback Signal Type - This parameter sets the type of feedback signal used when operating the HV amplifier channels in closed loop operation.

Two types of feedback signal are supported:

AC Strain Gauge - The AC Strain Gauge mode refers to the use of AC excited strain gauge feedback signals as generated by the complete range of Thorlabs piezo actuators and piezo equipped multi axis stages. All versions of the APT NanoTrak electronics support this feedback mode.

DC 0-10V - On APT modular hardware (and build 2 versions of benchtop APT hardware) it is possible to set the feedback signal type to DC 0 – 10V. This configures the feedback circuit to accept a differential 0-10V DC feedback signal in order to control position output. This latter feedback mode is available for use with third party piezo positioning systems capable of generating a standard voltage position feedback signal.

Note

On APT modular hardware (and build 2 versions of benchtop APT hardware), the function of the pin connections on the 9-way D-type feedback connector is dependent on the feedback mode selected. Refer to the pin-out tables in Section 5.2.3. for details.

4.6 Programmed NanoTrak Operation

Note

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

4.6.1 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 centre 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. 4.9.

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

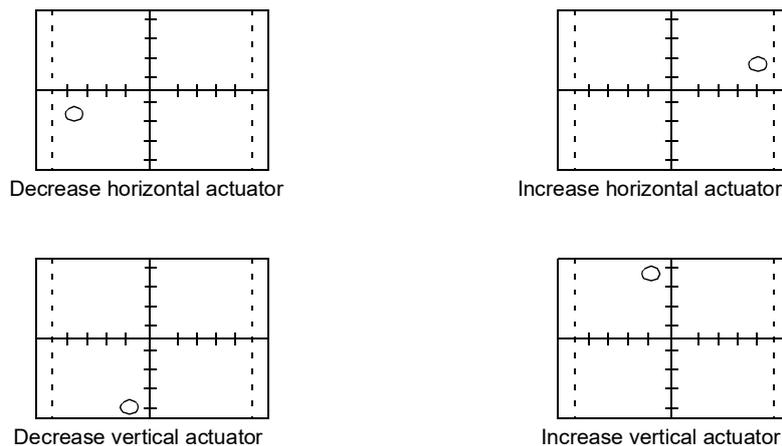


Fig. 4.9 CRT displays and actuator adjustments

4.6.2 Using an External Power Meter

Power meters are available that may give greater sensitivity and accuracy than the integral power meter of the NanoTrak. The output of the detector should be connected to the power meter, and the power meter O/P connected to the 'SIG IN' connector on the rear panel of the NanoTrak. The input defaults to a range of 1 V, although this can be changed to 2V, 5V or 10 V from the Settings panel – see Section 4.5.2.

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.

4.6.3 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) and 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 50 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. 4.10. The scan frequency and input source can be set either via the application software (see *APTServer Helpfile*) or directly via the Settings panel – see Section 4.5.2.

To set up a two NanoTrak system:

- 1) Make connections as shown in Fig. 4.10. - see Section 5.2.2. for USER I/O pinout details.
- 2) Power up the Rack.
- 3) Run APTUser, or your own application.
- 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 10Hz 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 'BNC 10V'.

Note

With BNC input source is 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/PIN connector on the master unit and the signal to the slave NanoTrak must be routed from the master USER I/O connector to the slave SIG IN (see Fig. 4.10). If using an external power meter, a T-splitter must be used on the SIG OUT connector of the master NanoTrak.

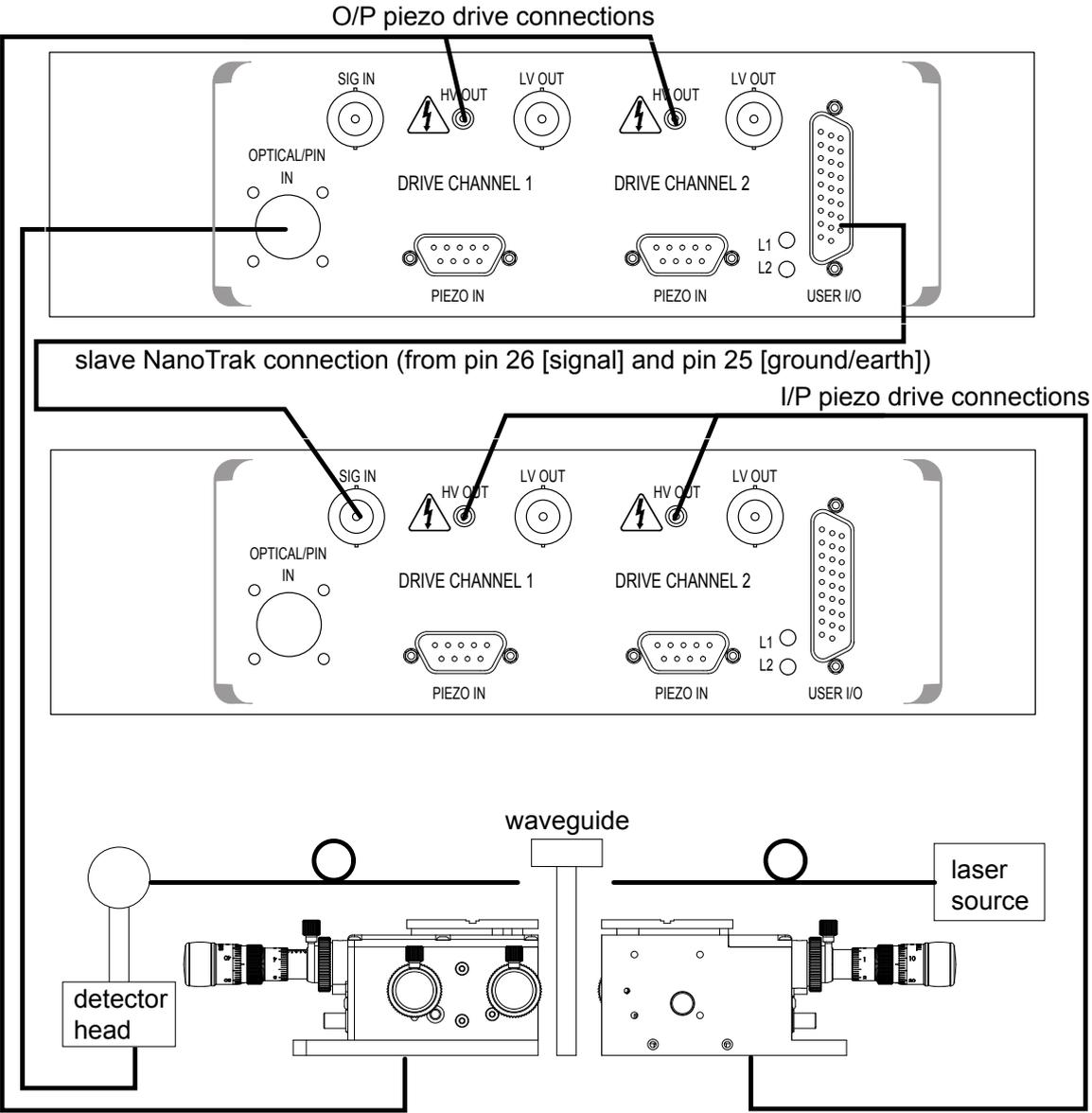


Fig. 4.10 Dual NanoTrak connections

Chapter 5 Installation and Maintenance

5.1 Mechanical Installation

5.1.1 Siting

The NanoTrak control module is intended for installation in the Midi Rack as part of the Thorlabs APT Modular Motion Control System. Full installation instructions are contained in the handbook *HA 0117 APT Modular Rack Handbook*.



Caution

When siting the unit, it should be positioned so as not to impede the operation of the rear panel power supply switch. Ensure that proper airflow is maintained to the rear of the unit.

5.1.2 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.

5.1.3 Identifying Unsafe Equipment

Whenever it is suspected that the safety of the product has been impaired, it is recommended that an appropriate label, recognized by your company, be attached and that the unit be removed to a place of repair.

5.2 Electrical Installation

5.2.1 Electrical 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 85V

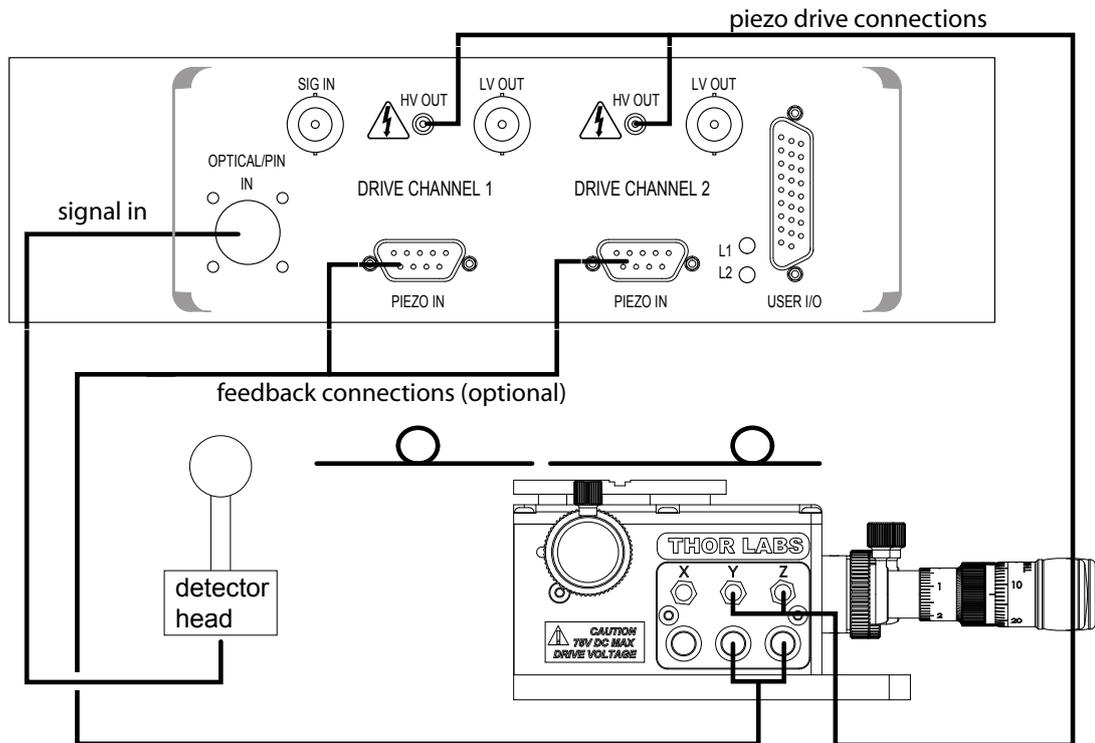


Fig. 5.1 Connecting the controller

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

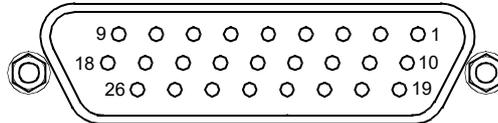
Referring to Fig. 5.1:

- 1) Using SMC-terminated cables, connect the 'HV OUT' terminals to the inputs of the stage corresponding to horizontal and vertical motion.
- 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 I/P. 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/PIN I/P' connector of the NanoTrak.

5.2.2 Rear Panel User I/O Connector

The User I/O connector exposes a number of internal electrical signals. For convenience, a number of logic inputs and outputs are included, thereby negating the need for extra PC based IO hardware. Using the APT support software, these user programmable TTL logic lines can be deployed in applications requiring control of external devices such a relays, light sources and other auxiliary equipment, or when operating a dual NanoTrak application. A 5V supply is required to power the digital outputs.

The pin functions are detailed in Fig. 5.2 and in each case must be referenced to the indicated return pin for the signal to be true..



Pin	Description	Return	Pin	Description	Return	Pin	Description	Return
1	* DIG I/P 1	19	10	* DIG O/P 1	19	19	** Isolated Ground	
2	* DIG I/P 2	19	11	* DIG O/P 2	19	20	Ext Trigger I/P	22
3	* DIG I/P 3	19	12	* DIG O/P 3	19	21	Ext Trigger O/P	22
4	* DIG I/P 4	19	13	* DIG O/P 4	19	22	Ground	
5	Channel 1 RS485 (+)		14	Channel 2 RS485 (+)		23	5V User O/P (Isolated)	
6	Channel 1 RS485 (-)		15	Channel 2 RS485 (-)		24	Not Used	
7	Not Used		16	Not Used		25	Analog Ground	
8	† Channel 2 10V O/P	25	17	External Analog I/P CH2 0 - 10V	25	26	‡ Signal Power Out	25
9	† Channel 1 10V O/P	25	18	External Analog I/P CH1 0 - 10V	25			

Notes.

- * Opto-isolated, TTL level signal.
- ** For use with digital signals.
- † For use with external signal monitoring equipment.
- ‡ For use with dual NanoTrak applications

Fig. 5.2 .NanoTrak User I/O Connector

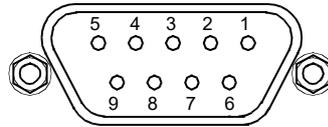
5.2.3 Rear Panel Piezo In Connector

Note

For use with piezo actuators with feedback capability.

The Piezo In connector provides the feedback connection from the piezo actuators (strain gauge).

The pin functions are detailed in Fig. 5.3..



Pin	Description	Return
1	Wheatstone bridge excitation	4 or 6
2	† +15V	4 or 6
3	† -15V	4 or 6
4	‡ d.c.(+) or Equipment ground	
5	Feedback signal in	4 or 6
6	Equipment ground	
7	‡ d.c.(-) or Actuator ID signal*	4 or 6
8	RS485(-)	9
9	RS485(+)	8

Notes.

† Power supply for the piezo actuator feedback circuit. It must not be used to drive any other circuits or devices.

* This signal is applicable only to Thorlabs actuators. It enables the system to identify the piezo extension associated with the actuator.

‡ Software switchable signal for strain gauge or d.c. feedback, see Section D.1.2.

Fig. 5.3 Piezo In connector - pin identification

5.3 Preventive Maintenance

**Warning**

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.

5.3.1 Cleaning

**Warning**

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.

Appendix A Troubleshooting

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

Answer.

- 1) Increase the size of the scan circle diameter.
- 2) Increase the gain.
- 3) Adjust the phase offset.
- 4) Check the connections (see Section 5.2.1.). 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 is adjusted.
- 5) 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.

Question. Given the answer 5) above, how can I verify that the NanoTrak is really tracking?

Answer. 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.

Question. Does the circle have to be precisely in the centre of the display?

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

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

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

Appendix B Specifications and Associated Parts

B.1 Specifications

Parameter	Value
Optical Power Measurement	
PIN Photo-Diode	FC/PC Fiber Input
Si or InGaAs Detector	1nA to 10mA Photocurrent
Signal Phase Compensation	-180° to 180°
NanoTraking	
Circle Scanning Frequency	1–300Hz
Circle Position Range	<1% to >99% MPE
Piezo Drive	
Connector	SMC male connector
Voltage Output	0 to 75V d.c. per channel
Voltage Stability	100ppm over 24 hours
Output Current	500mA per channel
Piezo In (feedback)	9 pin female D-type connector
User Control	26 pin female D-type connector
General	
Housing Dimensions (W x D x H)	190 x 270 x 50 mm (7.6 x 10.8 x 2.0 in.)
Instrument Weight	1.5 kg (3.3 lb)

2.2 Associated Products

Product Name	Part Number
APT Modular Rack	MMR601
InGaAs Detector	NTA007
Silicon Detector	NTA009
Drive Cable for Piezoelectric Actuators (3.0 m)	PAA100
Drive Cable for Piezoelectric Actuators (1.5 m)	PAA101
Piezoelectric Feedback Cable, Male D-type to Female LEMO converter (3.0 m)	PAA622

Appendix C NanoTrak Control Method Summary

The 'NanoTrak' ActiveX Control provides the functionality required for a client application to control one or more NanoTrak auto-alignment controller products. The NanoTrak system comes in both benchtop (BNT001) and 19" rack modular (MNA601) formats, both of which are covered by the NanoTrak ActiveX Control.

To specify the particular controller being addressed, every unit is factory programmed with a unique 8-digit serial number. This serial number is key to the operation of the APT Server software and is used by the Server to enumerate and communicate independently with multiple hardware units connected on the same USB bus. The serial number must be allocated using the HWSerialNum property, before an ActiveX control can communicate with the hardware unit. This can be done at design time or at run time.

The methods and properties of the NanoTrak control object can then be used to perform activities such as latching/unlatching, reading power levels, obtaining/setting circle size and position and determining if 'NanoTracking' is currently taking place.

For details on the use of the NanoTrak controller, and information on the principles of operation, refer to the NanoTrak Operating Guide.

A brief summary of each method and property is given below, for more detailed information and individual parameter descriptions please see the on-line help file supplied with the APT server.

Methods

DeleteParamSet	Deletes stored settings for specific controller.
DisableHWChannel	Disables the drive output.
DoEvents	Allows client application to process other activity.
EnableEventDlg	Enables or disables the event dialog box.
EnableHWChannel	Enables the drive output.
GetAmpFeedbackSig	Gets the feedback signal type (AC or DC).
GetAmpOutputParams	Gets the HV amplifier output parameters.
GetAmpControlMode	Gets the loop operating mode (open/closed).
GetCircDia	Obtains the user circle diameter setting
GetCircDiaLUTVal	Obtains the LUT value for the specified NanoTrak range, when automatic look up table (LUT) diameter adjustment mode is enabled.
GetCircDiaMode	Obtains the mode of circle diameter adjustment currently enabled
GetCircFreq	Obtains the circle scanning frequency
GetCircHomePos	Returns the circle home position horizontal and vertical coordinates
GetCircPosReading	Obtains the current horizontal and vertical position of the circle
GetInputSrc	Gets the HV amplifier input source.
GetLoopGain	Returns the feedback loop gain
GetLPFilter	Obtains the cut off frequency of the digital low pass (LP) filter applied to output readings of the internal amplifier (TIA) circuitry.
GetMaxTravel	Obtains the maximum travel for the piezo actuator associated with the specified channel of the activeX control instance.
GetParentHWInfo	Returns the serial number and hardware type identifier of the parent (or host) controller enclosure.
GetPhaseComp	Obtains the phase compensation setting for the horizontal and vertical components of the circle path.
GetRange	Returns the current range setting of the internal amplifier
GetRangingMode	Obtains the current ranging mode
GetRangingParams	Returns the autoranging characteristics for the NanoTrak input amplifier circuit
GetReading	Obtains the absolute signal value at the current position
GetTrackMode	Obtains the tracking mode settings
GetTrackThreshold	Obtains the tracking threshold of the NanoTrak
GetUnitsMode	Obtains the setting for units relating to the input signal measured by the NanoTrak.
Identify	Allows the hardware unit associated with the ActiveX control instance to be identified by flashing LEDs

Latch	Sets the tracking mode to 'Latched'
LLSaveHWDefaults	Allows the current settings of the operation parameters to be saved into the onboard 'Flash' memory of the hardware unit.
LLSetGetDigOPs	Sets or gets the status of the digital outputs on the APT unit associated with the ActiveX control instance.
LoadParamSet	Loads stored settings for a specific controller.
MoveCircHome	Moves the circle to the 'Home' position
SaveParamSet	Saves settings for the specific controller
SetAmpFeedbackSig	Sets the feedback signal type (AC or DC).
SetAmpOutputParams	Sets the HV amplifier output parameters.
SetAmpControlMode	Sets the loop operating mode (open/closed).
SetCircDia	Sets the user circle diameter
SetCircDiaLUTVal	Sets the LUT value for the specified NanoTrak range, when automatic look up table (LUT) diameter adjustment mode is enabled.
SetCircDiaMode	Sets the mode of circle diameter adjustment currently enabled
SetCircFreq	Sets the circle scanning frequency
SetCircHomePos	Sets the circle home position horizontal and vertical coordinates
SetHWMode	Sets the operating mode of the NanoTrak unit. (Piezo or NT)
SetInputSrc	Gets the HV amplifier input source.
SetLoopGain	Sets the feedback loop gain
SetLPFilter	Sets the cut off frequency of the digital low pass (LP) filter applied to output readings of the internal amplifier (TIA) circuitry.
SetPhaseComp	Sets the phase compensation for the horizontal and vertical components of the circle path
SetPowerCaptureParams	Used to store the power readings measured by the NanoTrak.
SetRange	Sets the range of the internal amplifier
SetRangingMode	Sets the current ranging mode
SetRangingParams	Sets the autoranging characteristics for the NanoTrak input amplifier circuit
SetTrackThreshold	Sets the tracking threshold of the NanoTrak
SetUnitsMode	Sets the units relating to the input signal measured by the NanoTrak.
ShowEventDialog	Shows the event dialog when it has previously been disabled using the EnableEventDlg method
StartCtrl	Starts the ActiveX Control (starts communication with controller)
StartPowerCapture	Starts the power capture process
StopCtrl	Stops the ActiveX Control (stops communication with controller)
StopPowerCapture	Stops the power capture process
Track	Sets the tracking mode to 'Track'.
TrackEx	Sets the scan pattern when the tracking mode is set to 'Track'.

Properties

APTHelp	Specifies the help file that will be accessed when the user presses the F1 key. If APTHelp is set to 'True', the main server helpfile APTServer will be launched.
HWSerialNum	specifies the serial number of the hardware unit to be associated with an ActiveX control instance.

Appendix D Using the Piezo Controller

D.1 Manual Operation - Piezo Controller

By calling the method SetHWMode in the APTServer, the NanoTrak can be placed into Piezo mode. This section explains the piezoelectric mode of operation.

D.1.1 Piezo Controller GUI Panel



Fig. D.1 Piezo Controller GUI panel

Note

The serial number of the APT unit associated with the ActiveX control instance (allocated using the HWSerialNum property), the APT server version number, and the version number (in brackets) of the embedded software running on the APT unit, are displayed in the top right hand corner of the control.

Channel - Used to select the applicable channel, when operating the 'Jog' and 'Output' controls. Also selects the channel data displayed in the 'Settings' window.

Output Control - used to adjust and set the voltage or position output as displayed in the main digital display. If the channel is in closed loop mode (set using the 'closed loop' button on the panel) then this control can be used to adjust position output. If open loop mode is selected (using the 'open loop' button) then the control is used to adjust the voltage output. Note that the read out in the main digital display is independent of the operating mode (open or closed loop) selected for the particular channel. If the 'Volts' button is selected, then the read out is in volts, even if the channel is in closed loop mode and the Output control is being used to adjust position. Similarly, if the 'position' button is selected, the read out is in microns, derived from the strain gauge feedback signal, even if the channel is operating in open loop.

Jog - used to increment or decrement the piezo position. When the button is clicked, the piezo is driven in the selected direction, one step per click. The step size can be set in the 'Settings' panel or by using the SetJogStepSize method.

Travel - the range of travel (in μm) of the piezo actuator.

Zero - used to zero the position sensor (strain gauge) when operating in 'Closed Loop mode' - see Setting The Position Sensor Zero.

Enable - enables or disables the HV channel's output voltage. With the piezo enabled, the LED in the button is lit. When disabled, the LED is unlit and the output voltage on the HV amp channel is set to zero volts.

Digital display - shows the voltage applied to the piezo, or the position (in microns), as determined by the feedback signal (if equipped). The display mode is set either via the 'Volts' and 'Position' buttons, or by calling the SetVoltPosDispMode method.

Volts and Position - push button controls used to toggle the display between volts and position modes - see Display Modes. The LED in the button is lit when selected.

Open Loop and Closed Loop - push button control used to toggle between open loop and closed loop modes. The LED in the button is lit when selected.

Settings display - shows the following user specified settings:

Jog Step Size - the distance to move when a jog command is initiated. If in closed loop mode, the step size is measured in microns; if in open loop mode, the step size is measured in Volts. The step size can be set either via the Settings panel or by calling the SetJogStepSize method.

Input Source - displays the input source associated with the selected channel. The input source can be set either via the 'Settings' panel or by calling the SetIPSource method.

If *SW Only* is displayed, the unit responds only to software inputs and the output to the piezo actuator is that set using the SetVoltOutput method.

If *+ ve BNC (+SW)* is displayed, the unit sums a positive analog signal on the rear panel BNC connector with the voltage set using the SetVoltOutput method.

If *- ve BNC (+SW)* is selected, the unit sums a negative analog signal on the rear panel BNC connector with the voltage set using the SetVoltOutput method.

Proportional - displays the proportional feedback loop constant for the selected channel (0 to 255).

Integral - displays the integration feedback loop constant for the selected channel (0 to 255).

Settings button - Displays the 'Settings' panel, which allows the tuning parameters to be entered - see Section D.1.2.

Ident - when this button is pressed, the LED on the front panel of the associated hardware unit will flash for a short period.

Active - lit when the unit is operating normally and no error condition exists.

Error - lit when one of the following fault condition occurs:

- 1) One or more power supply voltages are out of range.
- 2) Channel 1 or channel 2 has closed loop mode selected but the associated piezo is disconnected.

D.1.2 Piezo Controller Settings Panel

When the 'Settings' button on the GUI panel is clicked, the 'Settings' window is displayed for the selected channel. This panel allows data such as jog step size and input sources to be entered.

General tab.

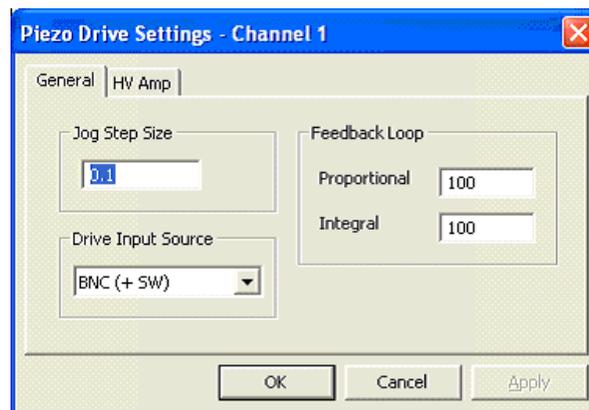


Fig. D.2 Piezo Settings panel - General tab

Jog Step Size - the distance to move when a jog command is initiated. If in closed loop mode, the step size is measured in microns; if in open loop mode, the step size is measured in Volts.

Feedback Loop - these parameters determine the response characteristics when operating in closed loop mode.

Proportional - sets the proportional feedback loop constant for the selected channel (0 to 255).

Integral - sets the integral feedback loop constant for the selected channel (0 to 255).

Input Source - determines the input source(s) which controls the output from the HV amplifier circuit (i.e. the drive to the piezo actuators).

SW Only - the unit responds only to software inputs and the HV amp output is that set using the SetVoltOutput method (or the GUI panel 'Output' control).

BNC (+ SW) - the unit sums the differential signal on the rear panel EXT IN (+) and EXT IN (-) BNC connectors with the voltage set using the SetVoltOutput method (or the GUI panel 'Output' control).

POT (+ SW) - the HV amp output is controlled by a potentiometer input (connected to the rear panel User I/O D-type connector) summed with the voltage set using the SetVoltOutput method (or the GUI panel 'Output' control).

BNC + POT + SW - the HV amp output is controlled by the sum of all three input sources (potentiometer, BNC's and software).

HV Amp Tab

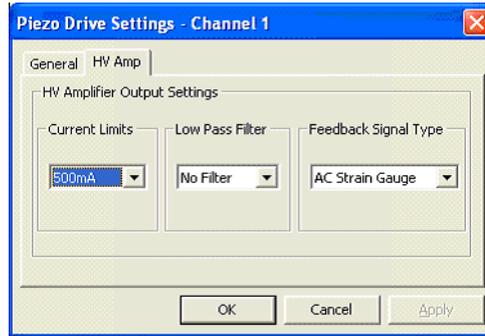


Fig. D.3 Piezo Settings panel - HV Amp tab

This panel is used to set the output characteristics of the HV amplifier channels fitted to the Piezo unit. Both low pass filtering and current control settings can be made to tailor the piezo output drive to a particular application.

Current Limits - This parameter sets the maximum current output of the HV amplifier:

- 100MA – Current output (piezo drive signal) limited at 100mA
- 250MA – Current output (piezo drive signal) limited at 250mA
- 500MA – Current output (piezo drive signal) limited at 500mA

Low Pass Filter – This parameter sets the cut off frequency of the hardware low pass filter, applied to the HV amplifier output channels. It applies to both channels simultaneously.

- 10HZ - Cut off all signals above 10Hz
- 100HZ - Cut off all signals above 100Hz
- 5KHZ - Cut off all signals above 5KHz
- NONE - Low pass filter inactive

Feedback Signal Type - This parameter sets the type of feedback signal used when operating the HV amplifier channels in closed loop operation.

Two types of feedback signal are supported:

AC Strain Gauge - The AC Strain Gauge mode refers to the use of AC excited strain gauge feedback signals as generated by the complete range of Thorlabs piezo actuators and piezo equipped multi axis stages. All versions of the APT Piezo electronics support this feedback mode.

DC 0-10V - On APT modular hardware (and build 2 versions of benchtop APT hardware) it is possible to set the feedback signal type to DC 0 – 10V. This configures the feedback circuit to accept a differential 0-10V DC feedback signal in order to control position output. This latter feedback mode is available for use with third party piezo positioning systems capable of generating a standard voltage position feedback signal - see note on next page.

Note

On APT modular hardware (and build 2 versions of benchtop APT hardware), the function of the pin connections on the 9-way D-type feedback connector is dependent on the feedback mode selected. Refer to the pin-out tables in Section 5.2.3. for details.

D.1.3 Setting the Position Sensor Zero

The position sensor is a strain gauge fitted to the piezo actuator. Due to limitations in manufacture, the strain gauge may give a small signal when the actuator is at zero position with zero volts applied. This 'offset' signal must be removed before the position attained by a specific applied voltage and the position attained by a corresponding specified distance can be rationalized. The offset is removed by clicking the 'Zero' button in the GUI panel or by calling the 'ZeroPosition' method in the application software.

Each actuator has a unique offset value. Therefore the offset should be adjusted whenever an actuator is replaced. Temperature and prolonged use can affect the performance of the strain gauge and therefore the offset value. It is good practice to adjust the offset value on a daily basis.

D.1.4 Choice of Display Mode

It is possible to set the GUI to display either the voltage applied to the actuator or the position measured by the sensor (in microns). Even if the module is in open-loop mode, the signal from the position sensor can still be displayed.

In the case of actuators with position feedback, there are 4 modes of operation in total;

- 1) Open-loop, display voltage applied to actuator

- 2) Closed-loop, display position (microns) measured by sensor
- 3) Closed-loop, display voltage applied to actuator
- 4) Open-loop, display position (microns) measured by sensor

Note

These options can be selected through the GUI 'Settings' panel or by calling the `SetVoltPosDispMode` method from the application software.

D.1.5 Detection of Range of Travel

In the case of actuators with position feedback, the Piezoelectric driver can detect the range of travel of the actuator, since this information is programmed in the electronic circuit inside the actuator.

It is possible to get the range of travel of the actuator from the application software by calling the `GetMaxTravel` method – see *Help File - APTServer*.

This feature is not present in actuators without position sensing.

Appendix E Principles of Operation

E.1 The NanoTrak

E.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 method is 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.

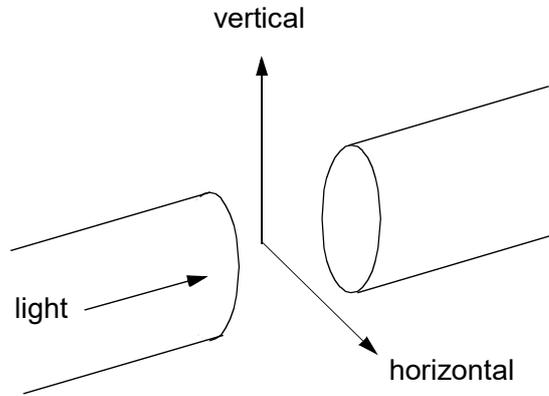


Fig. E.1 Alignment of optical fibers

In Fig. E.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. E.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.

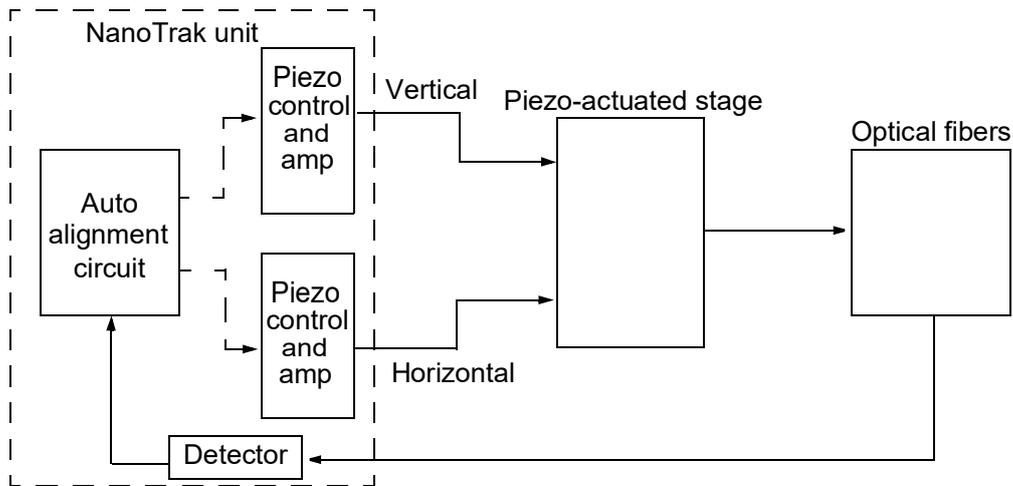


Fig. E.2 NanoTrak control loop

E.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. E.3, position A), the power is reduced. Furthermore, oscillating the fiber by a few microns causes the detected power signal to assume an a.c. component whose amplitude is proportional to the amplitude of the mechanical oscillation (modulating signal).

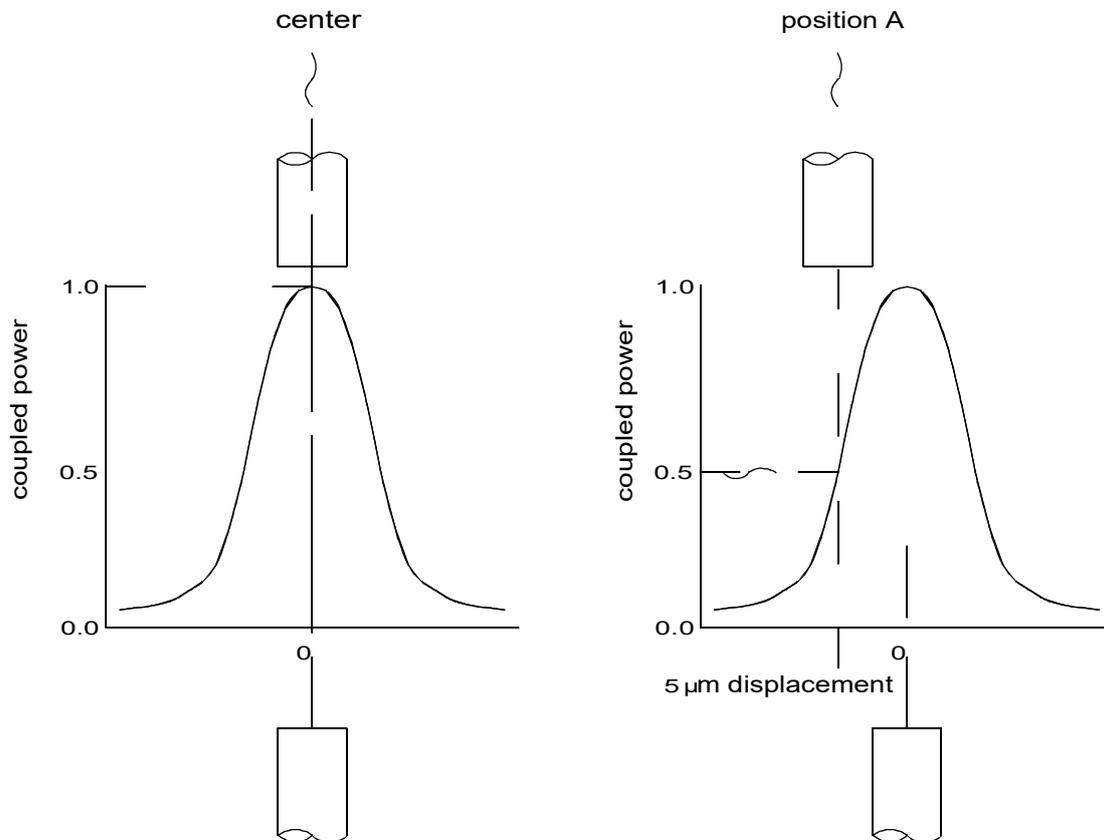


Fig. E.3 AC component of optical power

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 microns. 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. E.4 detail A.

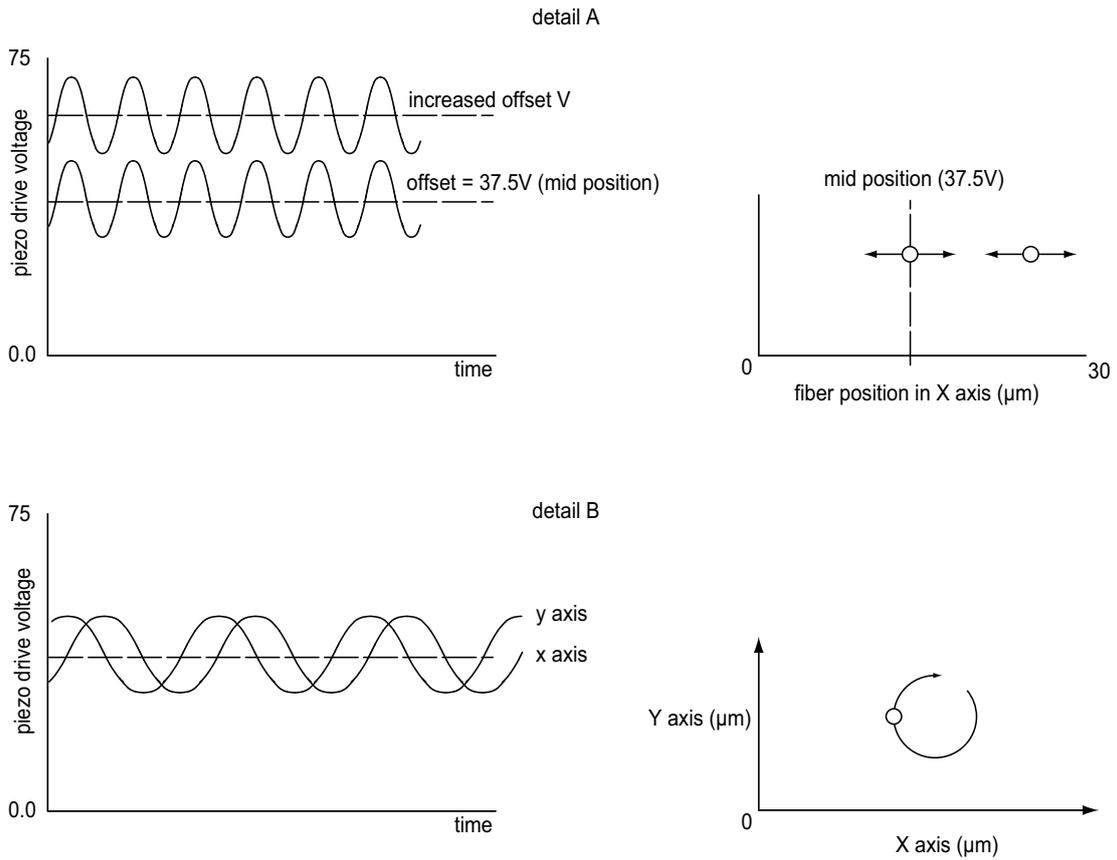


Fig. E.4 Offset voltage and fiber position

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. E.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*.

E.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. E.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.

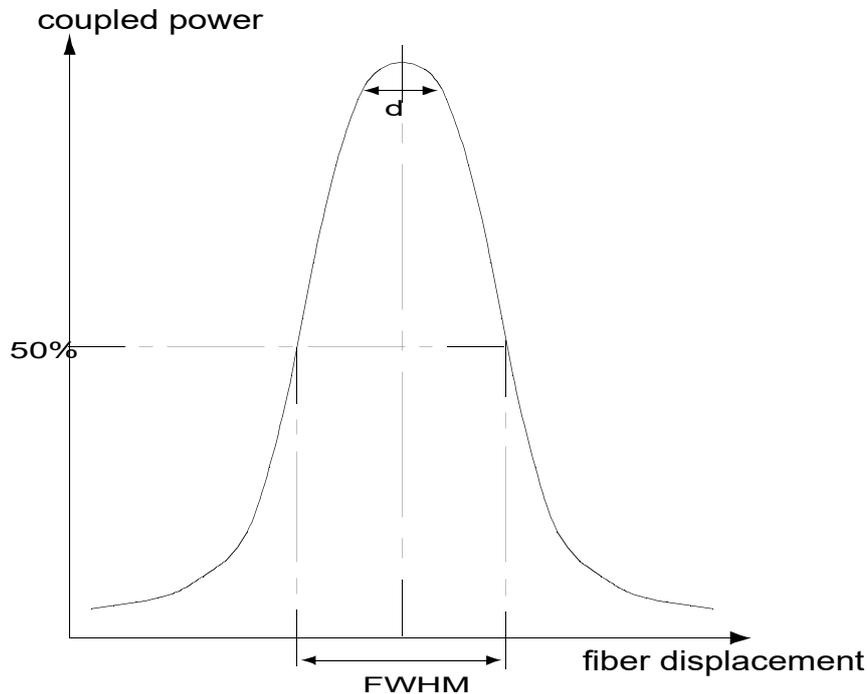


Fig. E.5 Circle diameter

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 50nm . At the point of optimized alignment, this small modulating signal results in a small a.c. 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 calling the SetCircDia method or entering a value in the Settings panel. Alternatively, if automatic LUT diameter adjustment mode is enabled (using the SetCircDiaMode method), 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.

E.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 APT 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.

E.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 has been located, which is sufficiently above the background noise level. See 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)

E.2 Piezoelectric Controller

E.2.1 The Piezoelectric Effect

Piezoelectricity is the effect whereby certain types of crystal expand reversibly when subjected to an electric field.

Although the amount of expansion is usually very small (corresponding to less than 1% strain in the material) it can be controlled extremely finely by varying the strength of the electric field. Piezoelectric materials therefore form the basis of very high precision actuators. The resolution of these actuators is effectively only limited by the noise and stability of the drive electronics. Moreover, the force generated by the expanding piezo is very large, typically hundreds of newtons.

Perhaps the most useful property of these actuators is their ability to produce oscillating motion at considerable frequencies, usually limited by the mechanical system driven rather than by the piezo actuator itself. This ability is used to advantage in the NanoTrak control system, for example.

The electric field gradient needed to produce a useful amount of expansion is quite large. Thus to avoid excessive drive voltages, the actuator is constructed as a stack, consisting of lamina of active material sandwiched among electrodes – see Fig. E.6. In this way, the distance from positive to negative electrodes is very small. A large field gradient can therefore be obtained with a modest drive voltage (75 V in the case of Thorlabs actuators).

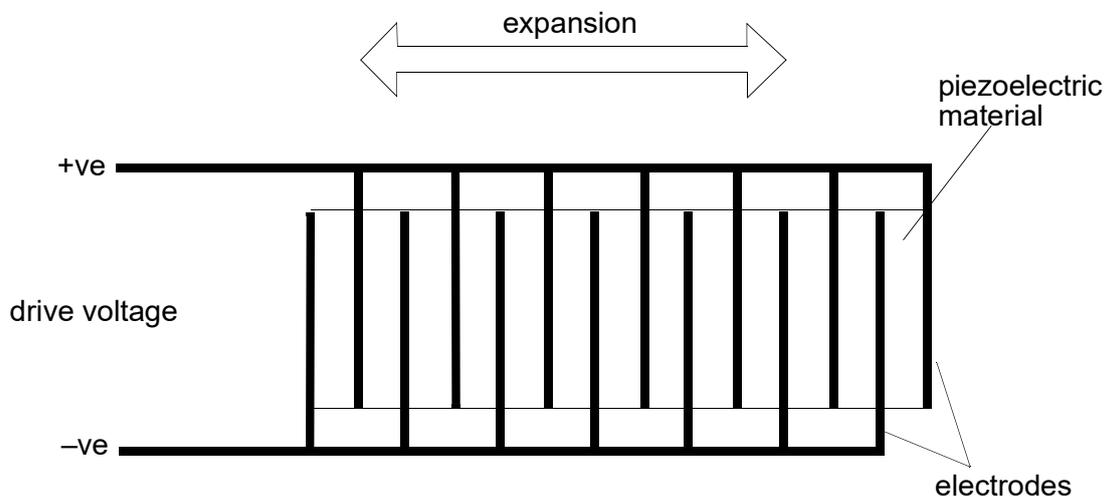


Fig. E.6 Piezo-electric actuator schematic diagram

E.2.2 Hysteresis

Despite the very high resolution of piezoelectric actuators, an inherent problem is the significant amount of hysteresis they exhibit, (i.e., the tendency of the actuator to reach a final position that lags behind the demand position).

If a cyclic voltage is applied to the actuator the positions reached on the upward sweep are smaller than those achieved on the downward sweep. If position is plotted against voltage, the graph describes a hysteresis loop – see Fig. E.7.

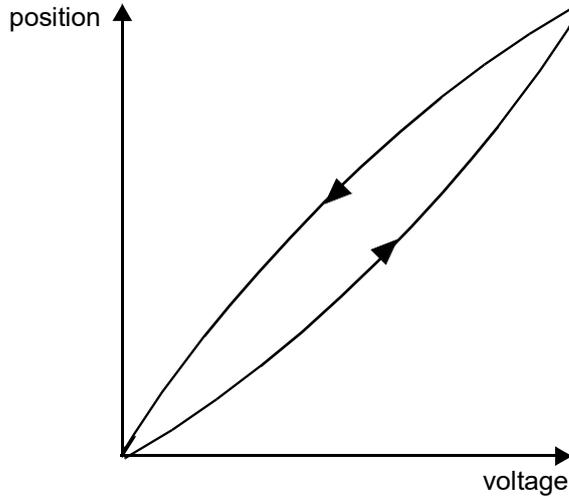


Fig. E.7 Piezo-electric hysteresis

E.2.3 Position Sensing and Feedback Control

Hysteresis can be eliminated by using a position sensor and feedback loop, i.e., the sensor measures the position, the circuit subtracts the measured position from the demand position to get the error, and a proportional-integral feedback loop adjusts the voltage to the actuator until the error is virtually zero.

Some Thorlabs nanopositioning actuators have position sensing, others do not. The Piezoelectric control module allows both types to be controlled.

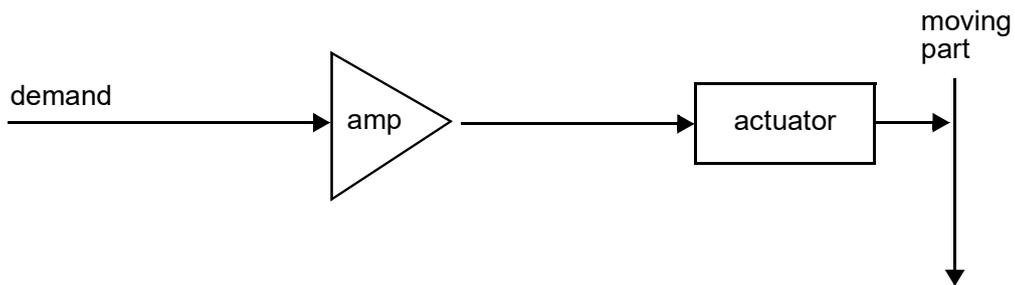
To control an actuator with position sensing, the Piezoelectric control module should be set to closed-loop mode. To control an actuator without position sensing, the Piezoelectric Control module should be set to open-loop mode.

Note

An actuator with position sensing can also be driven in open-loop mode if desired, since the feedback part of the circuit can be switched off. An advantage of open-loop mode is the greater bandwidth of the system.

Block diagrams for both modes of operation are shown in Fig. E.8.

Open loop control



Closed loop control

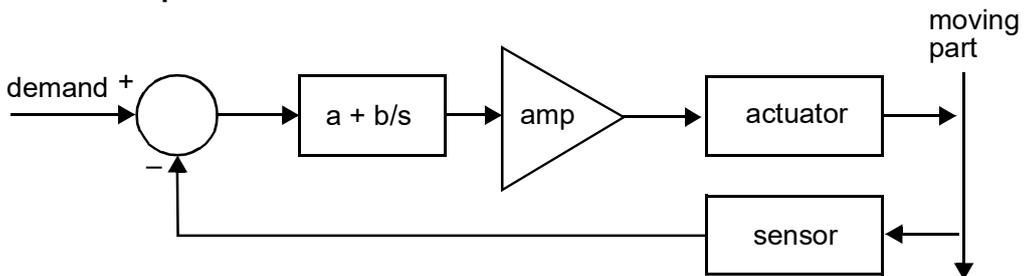


Fig. E.8 Open loop and closed loop control

The result of using closed-loop control is a linear relationship between demand (voltage) and measured position – see Fig. E.9, in contrast to open loop control – see Fig. E.7.

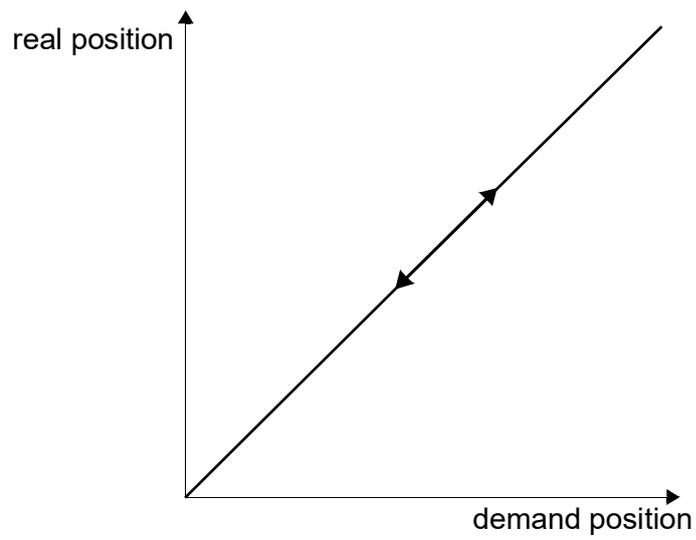


Fig. E.9 Closed loop response

Appendix F Regulatory

F.1 Declarations Of Conformity

F.1.1 For Customers in Europe



E C Declaration of Conformity

We,

Thorlabs Ltd
1 Saint Thomas Place,
Cambridgeshire Business Park,
Ely, Cambridgeshire
CB7 4EX

declare that the MNA601/IR auto-alignment control module complies with the following Harmonized European Standards:

BS EN 61326-1:1998
BS EN 61000-3-2: 2000
BS EN 61000-3-3: 1995
EN 61010-1: 2001

And is in conformity with

93/68/EEC – CE Marking Directive (1996)
89/336/EEC – EMC Directive (1996)
73/23/EEC – Low Voltage Directive (1997)

Signed in **Ely**
(place)

On the 8 day of November 2011
(day) (month) (year)

Name: Keith Dhese

Position: General Manager

F.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.

Appendix G 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.



USA, Canada, and South America

Thorlabs, Inc.
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sales@thorlabs.jp

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brasil@thorlabs.com

China

Thorlabs China
chinasales@thorlabs.com

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 dissembled 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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