INDUSTRIAL SENSORS & PROCESS AUTOMATION

USER'S MANUAL

ATF6 Auto Focus and Proximity Sensor

October, 2015 Edition

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Chapter 1

INTRODUCTION

1.1. ORGANIZATION OF THE MANUAL

Chapter 1: Introduction - Information about contents of this manual. Also contains warranty and compliance details.

Chapter 2: Functional Description - A description of the *WDI* ATF6 Sensor.

Chapter 3: Interfacing ATF6 - Provides description and details about mechanical interface, optical interface, electrical interface and sensor software interface.

Chapter 4: Sensor Alignment - Contains instructions for sensor setup, alignment and adjustment.

Chapter 5: Special Application - Describes extended sensor functionality.

Chapter 6: Specifications - Provides performance data and physical details.

Chapter 7: Serial Communication Protocol - Provides details for interfacing via serial communication, and functionality as a result of integration test.

Chapter 8: WDI Test Software - Details, methods, and software tools required for test and verification of the ATF6 sensor.

Chapter 9 WLoader Application - Describes usage and installation of the WLoader program for reloading and updating ATF6 sensor application software and firmware.

1.2. CHANGES TO WDI PRODUCTS

WDI reserves the right to improve, change or modify its products without incurring any obligations to make changes to previously *WDI* equipment sold.

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1.3. WARRANTY

WDI warrants its equipment for a period of 1.5 years from the date of shipment, provided that it is installed exactly as defined in associated ***WDI*** documentation and the warranty seal has not been broken.

Prior consent must be obtained from ***WDI*** if non-***WDI*** equipment (e.g. power supply and/or cabling) is to be used or substituted. Failure to comply with this will invalidate the ***WDI*** warranty.

1.4. COMPLIANCE

FCC "Declaration of Conformity Information"

This equipment has been tested and found to comply with the limits of a Class A digital device (FCC section 15.105), 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 generate, use 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.

Information to user (FCC section 15.21)

The user is cautioned that any changes or modifications not expressly approved by ***WDI*** or an authorised representative could void the user's authority to operate the equipment.

Special accessories (FCC section 15.27)

The user is also cautioned that any peripheral device installed with this equipment such as a computer, must be connected with a high-quality shielded cable to insure compliance with FCC limits.

Laser Compliance

ATF6 Sensor was tested and found to comply with International Electrotechnical Commission IEC60825-1 and European Norm EN60825-1 regulations for Class 1 laser products.

LASER RADIATION
DO NOT STARE INTO BEAM
CLASS 1 LASER PRODUCT

MAX. POWER: < 0.75mW
WAVELENGTH: 660nm,785nm
EN60825-1: 2007

VISIBLE & INVISIBLE
LASER RADIATION
AVOID EXPOSURE TO BEAM
CLASS 1 LASER PRODUCT

Any modification or change made to the product without explicit approval from ***WDI***, by means of a written endorsement or through published literature, invalidates the warranty agreement with ***WDI***.

Declaration of Conformity

WDI
WISE DEVICE INC

Halszka Weiss MBA, H.Bsc.

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WDI Wise Device Inc
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March 16, 2015

Declaration Of Conformity

in accordance with Directive 2006/95/EC
of the European Parliament

Equipment Description: Autofocus Sensor

Equipment Model Designation: ATF2LV, ATF4 SYS/SA, ATF5 CM, ATF5 SYS, ATF6 CM/SYS/SA

Manufacturer: WDI Wise Device Inc

Manufacturer's Address:

80 Gough Rd
Markham ON L3R 6E8
Canada

Directive:

2006/95/EC - Low Voltage Directive
2004/108/EC - Electromagnetic compatibility

Standards:

IEC 613621-1: 2005
IEC 613621-1: 2006
IEC 60825-1: 2007
IEC 62471: 2006

I, the undersigned, representing the manufacturer, declare in sole responsibility, that the product specified above, to which this declaration relates, conforms to the above mentioned Standards and Directives.

Place Of Issue: Markham, Ontario, Canada

Date Of Issue: March 16, 2015

Halszka Weiss MBA, H.Bsc.

Chapter 2

FUNCTIONAL DESCRIPTION

2.1. INTRODUCTION

The ***WDI*** Automated Tracking Focus (ATF6) sensor is an active optical device designed for providing focusing servo systems with fast feedback signals needed to quickly and accurately focus almost every type of infinity corrected microscope.

The sensor determines the direction towards focus as well as measures the distance to the best focus position.

The ATF6 projects reference laser spots through the microscope's own objective lens. This eliminates a need for surface features in judging the degree of focusing and thus the sensor operates equally effectively on patterned and un-patterned specimen as well as tolerates diffusing and reflective surfaces (including thin and thick glass sheets).

The ATF6 projects line shaped laser beam. Each line segment is a source of distance to focus measurements. This redundancy of information improves sensor accuracy and facilitates reliable operation on patterned media such as TFT arrays or photo-masks.

Since the ATF6 sensor measures the distance to focus, it is effective regardless whether the specimen is stationary or in motion. This last feature (often referred to as tracking auto-focus) is particularly useful when multiple images of spatially distributed areas must be quickly collected from a specimen. In such cases tracking auto-focus eliminates the focusing overhead time and improves the instrument throughput.

The sensor's performance is unaffected by the ambient lighting and the microscope's illumination.

The ATF6 sensor is a Class 1 laser device projecting a visible spot onto the specimen.

The sensor contains no moving parts and thus is practically maintenance free.

2.1.1 ATF6 SPECIAL FEATURES

The speed is aimed for high speed tracking applications:

- Patterned wafer inspection
- Wafer processing
- Photo mask inspection and repair
- CVD TFT repair
- Laser micro-machining
- For three dimensional periodical structures, such as MEMs or touch screens, the user can choose to keep focus on either the substrate or high spots

The ATF6 sensor operates well on almost all types of surfaces:

- Reflective and diffusing
- Low reflectivity surfaces (down to 1%)
- Transparent and opaque
- Plane, patterned(Silicon Wafer) and textured

- Fast automatic laser intensity control (dynamic range 1:1000) to enable reliable operation on the specimen ranging in reflectivity from 1 to 99% and characterized by rapid reflectivity changes such as TFT arrays.
- Internal offset correction for the entire range of objectives.
- Internal output characteristic linearization.
- ATF6 covers the range of microscope objectives from 1x to 100x as well as speciality objectives such as NIR, NUV and UV.
- ATF6 can operate as an auto-focus sensor and a precise proximity gauge.
- Provides features to eliminate the laser reference line from the camera image.
- Optionally incorporates an integrated stepper motor controller for operating an autonomous closed loop auto-focus servo system.
- Optionally integrates an intensity controller for the white LED field light illuminator.

2.1.2 ATF6 PRINCIPLE OF OPERATION

The sensor operates on the principle of monocular triangulation for assessing the direction and distance towards focus (the monocular triangulation is often referred to as ***Through The Lens*** – TTL – triangulation).

For some applications - for instance TFT array repair - in the rapid transition areas between highly reflective traces and low reflectivity ITO electrodes, the image of the laser illuminated area becomes distorted by variations of material reflectivity. This leads to measurement errors. To alleviate this difficulty, the ATF6 projects laser line that supplies redundant information available in each line segment.

The ATF-6 sensor uses the 658 or 785 nm laser beam to project the reference line on the specimen. The laser needs to be coupled with the microscope in its infinity range through the beam-splitter (optical port). The laser beam covers fraction, up to half, of the objective's aperture [

FIGURE 2-1].

After passing through the objective, the laser beam degenerates to a line in focus or appears as a rectangle to the left or right of the main optical axis depending whether the specimen is below or above focus.

The line width changes are measured by the internal sensor's imaging sensor and are converted by the S/W to the distance to focus measurements. In the vicinity of focus the optical point spread function is analyzed to further improve the accuracy of the in-focus indication. The senor utilizes the fast CMOS area scan photodiode array and the Field Programmable Gate Array as the real time pixel processor.

The sensor is equipped with digital I/Os to synchronize it with other equipment: usually when the imaging system is exposing, the laser is turned off to prevent the laser line from appearing in the image.

United States Patent Application 20030184765 and United States Patent 33,774 protects optical configuration of the ATF auto focus sensor.

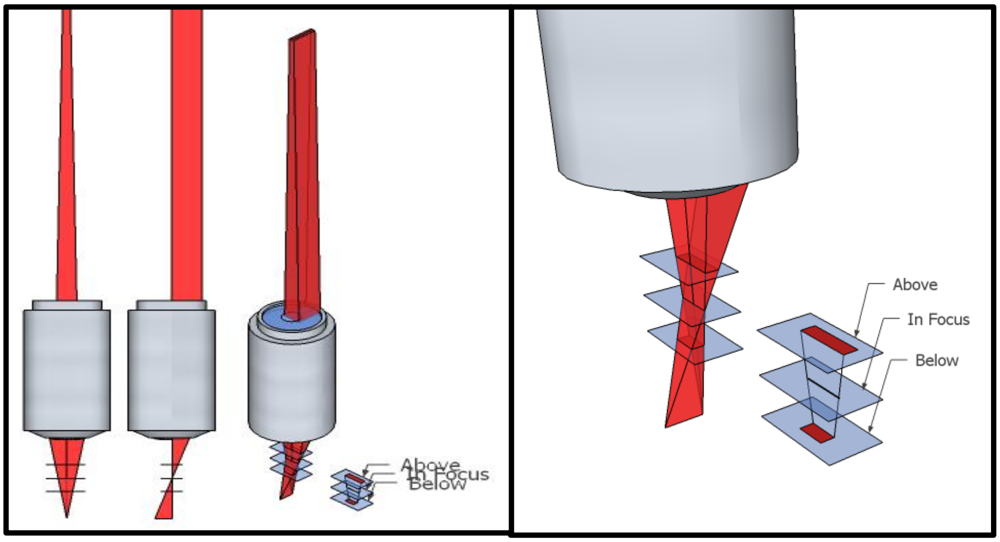

Figure 2-1 Principle of operation

2.1.3 ATF6 Output Characteristics and Digital I/O

The sensor's output characteristic is internally linearized to match the objective lens (easy to use calibration software is provided).

The distance to focus measurement is always available on the sensor's RS232 communication link. Sensor optionally equipped with the analog output also presents this information in the form of an analog voltage signal.

If the specimen is out of sensor range, the sensor's output is set to 0 DU (0 volts on the analog output) and the ***In Capture Range*** DIO signal is low. Once the specimen is detected, the ***In Capture Range*** DIO signal is asserted.

For as long as the specimen is far from focus, the sensor's output remains at 512 DU and the sign of the output indicates the direction towards the In Focus position (for sensors equipped with the analog output the voltage is set to either -

8 V or +8 V depending on the direction to focus).

In the vicinity of focus the sensor's characteristic is linear i.e. the output is proportional to the distance to focus.

Once the microscope reaches the In Focus position, the ***In Focus*** DIO signal is asserted. The ***In Focus*** DIO signal remains high as long as the microscope objective is maintained within its depth of field (DOF). The width of the DOF can be configured with the software.

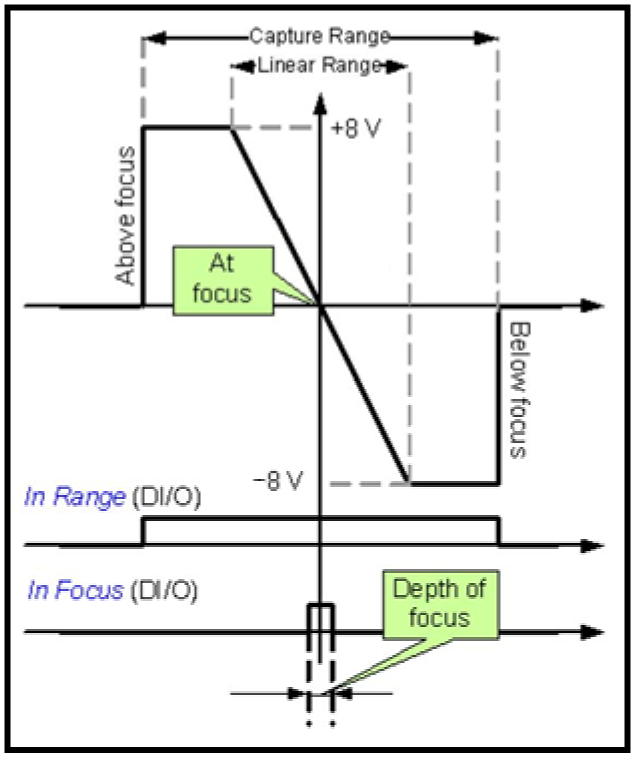

Figure 2-2 Sensor's output characteristic and digital I/O

In addition to the status signals (***In Capture Range*** and ***In Focus***), the ATF6 is equipped with two control digital inputs:

Laser Enable DIO for deactivating the sensor's laser and suspending the auto-focusing functions. This signal is intended to be incorporated with the laser safety interlock.

Camera Sync DIO for deactivating the sensor's laser in sync with the microscope's imaging system (laser is turned off when the imaging system is exposing).

2.1.4 TYPICAL APPLICATION

For installation, the ATF6 sensor requires an optical port in the infinity range of the microscope and a customized mounting bracket for attaching the sensor. The sensor's output is sent to the auto-focus servo controller for automatic adjustment the microscope objective "Z" position.

If application assistance is required, please contact ***WDI***.

There are two options to interface a user supplied servo-controller to the sensor:

- using a serial (RS232) communication link,
- using the sensor's analog output and digital inputs and outputs

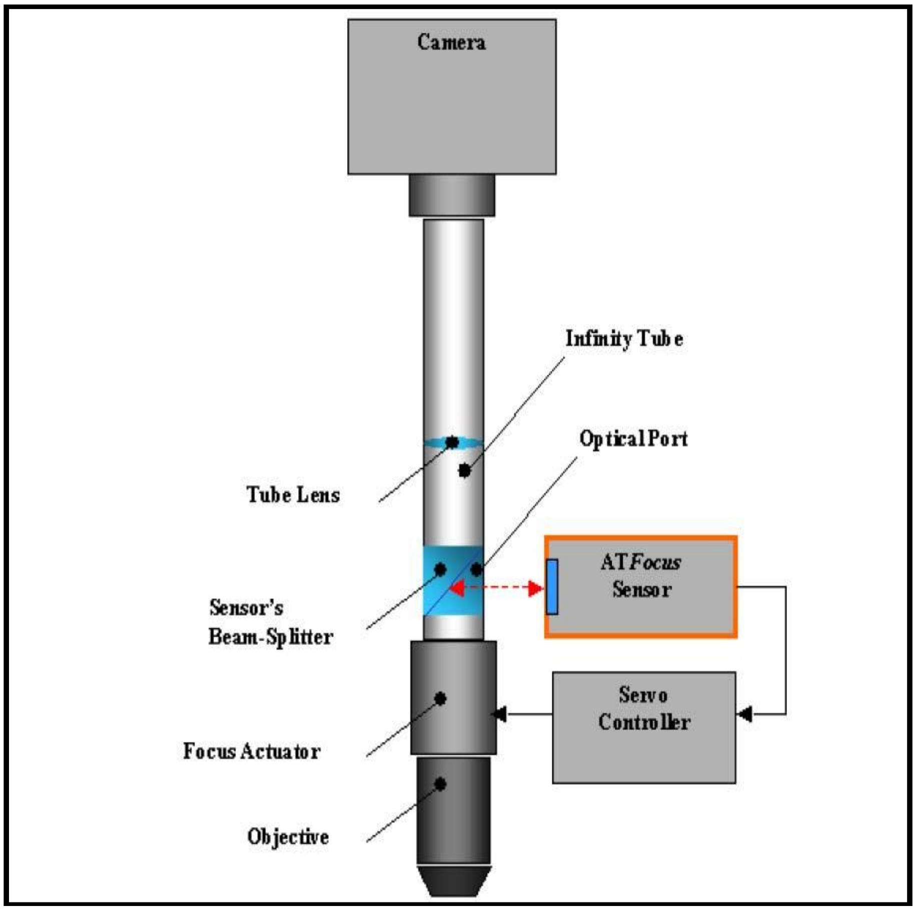

Figure 2-3 Auto Focus System Components

2.1.5 ATF6 OPTIONS

There are two ATF6 Options available:

1) The standalone auto-focus sensor (ATF6SA)
   - Stand-alone sensor; controller is not included.
   - The standalone sensor model (ATF6SA) can be electrically interfaced using the analog output and/or RS232 communication link to convey the sensor measurements.
2) The Auto-Focus System sensor (ATF6SYS)
   - The Auto Focus System includes a sensor with an integrated servo controller for driving the stepper motor actuated auto-focus servo mechanism (ATF6SYS & Servo Controllers i.e. MCM+,MCZ,MFC)
   - The ATF6 SYS Selections:

     I. ATF6-C
        - Autonomous autofocus system for LCD cell inspection/repair.
        - The focus is on the user-selected surface of the multi-layer transparent structure.

     II. ATF6-CM
        - CM sensor stands for "Cell and Module sensor." WDI models ATF5 CM and ATF6 CM are well suited for focusing on multiple transparent layers, such as TFT cells.
        - The CM sensor analyses and differentiates the reflections from each surface in a multi-layer medium. Called "surface recognition," the sensor is instructed to use the desired surface, based on user's configuration.

     III. ATF6-PZ

NOTE: THE ATF6SYS MODELS ARE NOT EQUIPPED WITH THE ANALOG INTERFACE.

2.1.6 ATF6 GENERAL SPECIFICATIONS

The accuracy of auto-focusing with ATF sensors is limited by the objective lens rather than the sensor itself; therefore the accuracy figure is better approximated in units of the objective's depth of field (DOF), sometimes also called "depth of focus."

Minimum Accuracy	
Static Autofocus	±1/4 DOF
Fast tracking autofocus	±1/2 DOF

The ATF sensors' capture range is defined as the maximum deviation from the best focus that the sensor can reliably assess for bringing the optical system back to focus. Similarly to accuracy, the capture range is also affected by the objective Numerical Aperture (NA) and its optics design. As an example, the table below summarizes the ATF sensors' capture range for Mitutoyo long working distance M Plan APO objective lenses.

ATF Sensors Capture Range					
Magnification (NA)	5X(0.14)	10X(0.28)	20X(0.42)	50X(0.55)	100X(0.70)
Capture Range [um]	±2500	±1000	±500	±250	±100

WDI paid particular attention to designing the ATF sensors family such that minimal integration effort is required from the user. The mechanical integration is facilitated by the compact ATF sensor design. All the members of the ATF sensor family share the same footprint and are electrically pin to pin compatible with one another to enable easy upgrades.

Chapter 3

INTERFACING WITH ATF6

3.1. MECHANICAL INTERFACE

The ATF6 sensor should be installed on a user provided base plate with four mounting screws. Two sets of threaded mounting holes are available at the sensor base (M2.5 and M3).

The mounting screws must not penetrate the sensor housing any deeper than 5 mm.

WARNING: USING LONGER SCREWS MAY DAMAGE THE SENSOR OR IRREVERSIBLY UPSET ITS INTERNAL ALIGNMENT.

Please refer to Figure 4-7 for the detailed mounting screws configuration.

The sensor should be mechanically integrated such that a space is left at the back of the sensor (connector side) of at least 55 mm, 30 mm to accommodate the sensor's electrical connector and a 25 mm allowance for the sensor's cable bending radius.

Approximately 50 mm of space must be left unobstructed to allow access to the sensor adjustment screws. The sensor alignment adjustments must be performed with a 1.5 mm hex key (Allen key). The required space allowances are shown in [FIGURE 3-1].

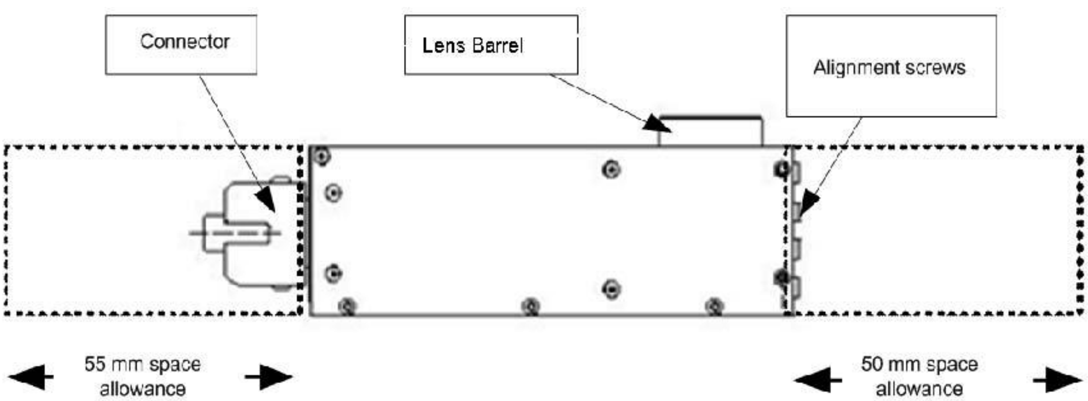

Figure 3-1 Mechanical Clearance - Sensor's Top view

3.2. MECHANICAL INTERFACE BETWEEN ATF6 AND MICROSCOPE

An example of a mechanical interface between the ATF6 and a microscope is shown in **[Figure 3-2].** Mechanical Interface of the ATF6 with a Microscope.

Aligning the sensor within a microscope requires a minimum of two degrees of freedom; a sensor sidewise shift of ±5 mm facilitated by the slotted holes in the sensor's mounting plate and the guiding hard edge on the base plate, at least one kinematic mounted beam splitter interacting with the sensor.

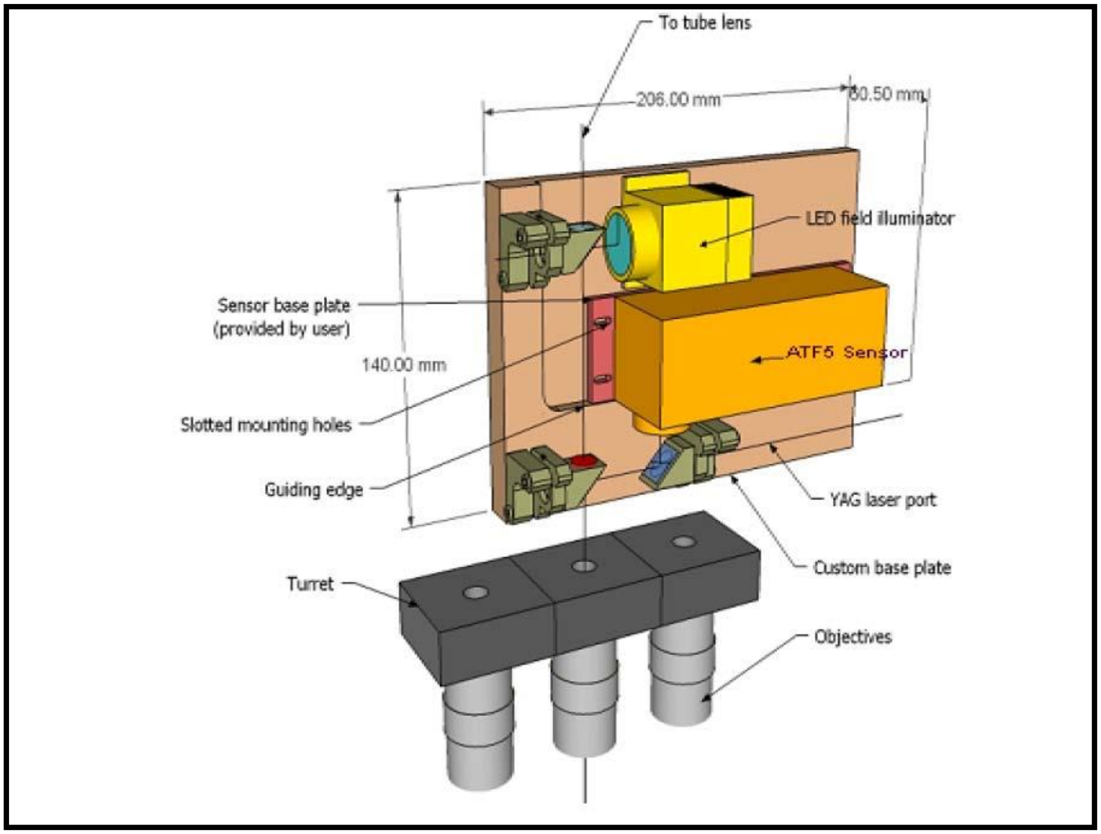

Figure 3-2 Mechanical interface of the ATF6 with a microscope

3.3. OPTICAL INTERFACE

For the optical interface, the ATF6 sensor requires an optical port in the infinity range of the microscope.

The sensor's optical port, in the infinity range of the microscope, must be equipped with an optical notch filter. The notch filter selectively reflects laser light emanating from the sensor and passes through the rest of the visible spectrum.

The example notch filter characteristic, suitable for the ATF6, is shown in the [FIGURE 3-3].

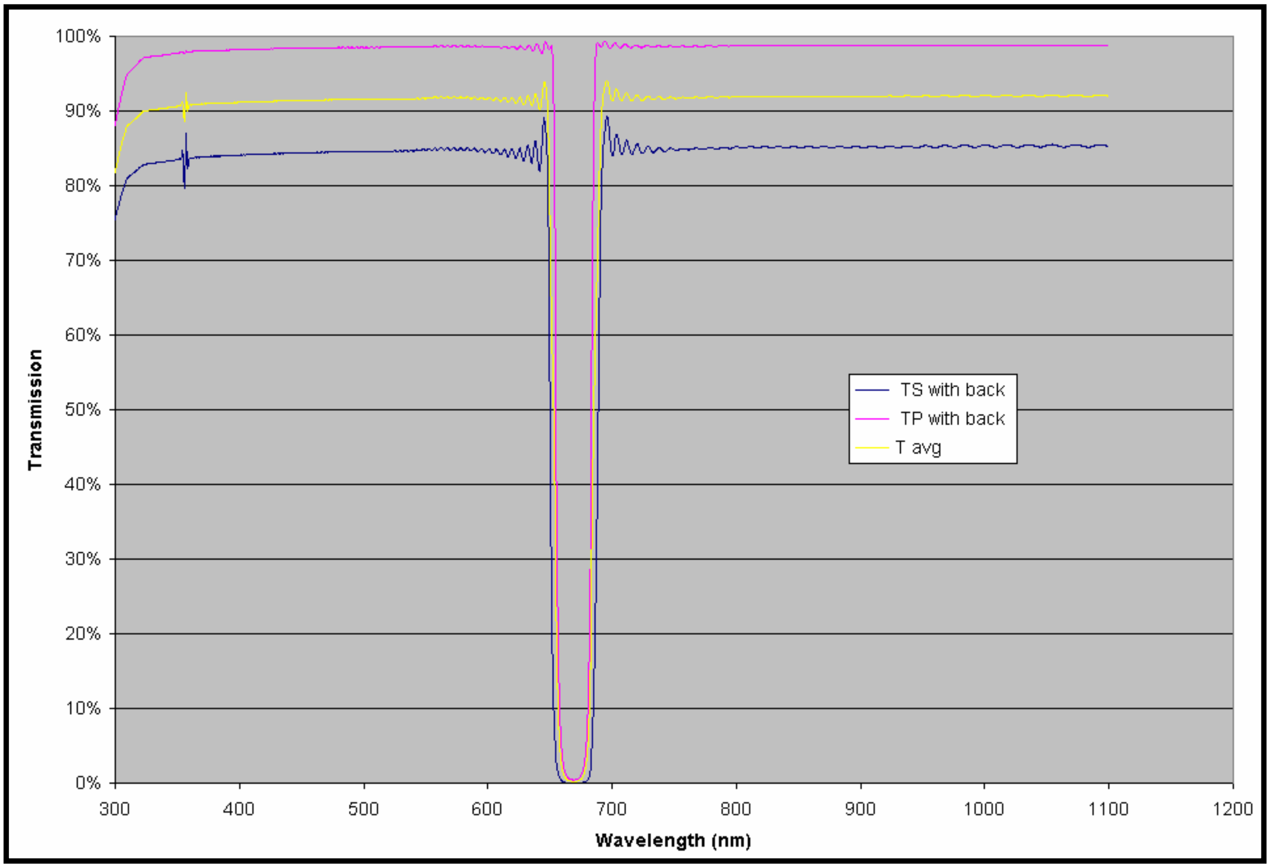

Figure 3-3 An example of the notch filter spectral characteristic.

The optical notch filter assembly has to facilitate fine alignment as indicated by arrows in Figure 3-4

The optical port closets to the objective lens should be assigned for ATF6 sensor interface, if this is not possible please contact ***WDI*** for sensor integration assistance.

The sensor also requires a translation type adjustment with a range of at least ±5mm as indicated by the vertical arrow in Figure 3-4

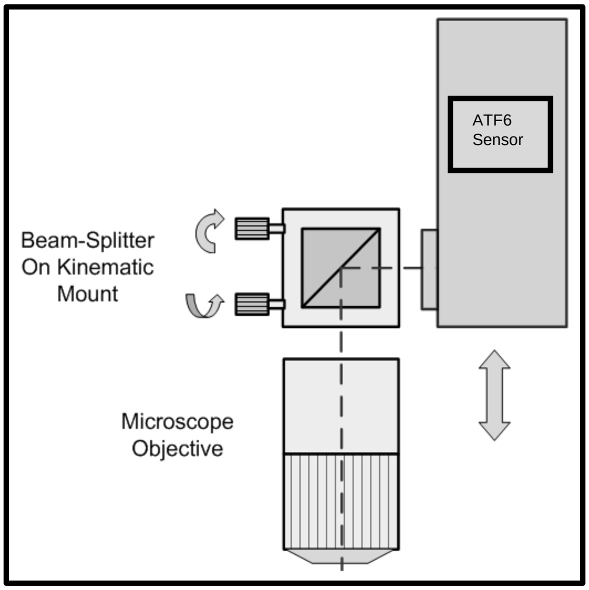

Figure 3-4 Optical Interface

3.4. ELECTRICAL INTERFACE

3.4.1 ELECTRICAL INTERFACE FOR THE STANDALONE AUTO-FOCUS SENSOR (ATF6SA)

3.4.1.1. *Connecting Cable Options*

The ATF6SA sensors are provided with the standard 6 foot (1.8 m) cable. The cable is terminated on the sensor side with a Hirose HRS-3500, 16 pin connector. The user's end is terminated with DB15M (male) connector. If a longer length of cable is required, it is suggested to use a DB15 extension cable.

Table 3-1 Connector Cable Options

Part Number	Length	Comments
HRDB-6	6' (1.8 m)	Standard

****Other cabling solutions are also available as a custom order.*

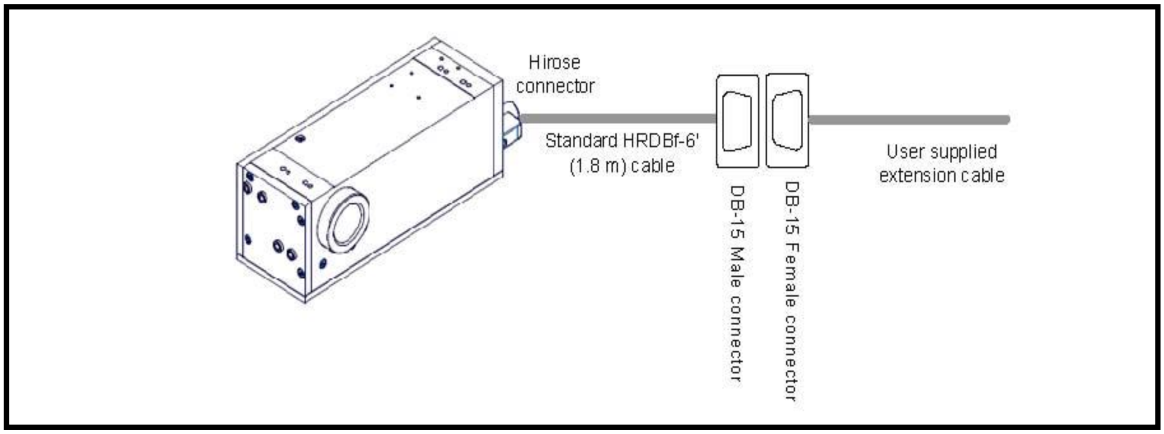

Figure 3-5 Cabling Overview

Table 3-2 ATF6SA Pin Assignment

Pin Number	Name	Comments
1	+12 V	Sensor Positive Power
2	0 V	Sensor supply return, Digital I/O return
3	0 V	Sensor supply return, Digital I/O return
4	-12 V	Sensor Analog Output (AO) Negative Supply
5	Analog out	± 8 V Full Range
6	0 V	Analog return out
7	In Capture Range	Open Collector Output Low when asserted.
8	In Focus	Open Collector Output Low when asserted.
9	Reserved	Do not connect
10	Laser enable	Input, disable the laser when negated.
11	Camera sync	Input Disable the Laser when asserted while maintaining the current position.
12	Reserved	Do not connect
13	TxD	RS232
14	RxD	RS232
15	0 V	RS232 return

User supplied connections consist of four groups: power and RS232, analog output, digital inputs and digital outputs. These are explained below.

Pin references and connector orientation are with respect to the customer supplied DB15 female connector. In all diagrams, pin 1 is always identified.

It is recommended that ***WDI***'s 1.8m ATF6 sensor cable be used at the sensor end and, if required, an intermediate DB15 extension cable runs through the E-chain to the control electronics cabinet. One consideration for this extension cable is that it be of high flex wire. This type of cable would be easy to replace in the event that it should fail as there are DB15 connectors at both ends.

Other considerations for the extension cable are:

- the extension cable must be broken into groups of signals to avoid cross talk associated with long cable lengths
- the analog pair should be in a separate cable
- the RS232 signals (pins 13, 14 and 15) should be in a separate cable
- the power wires (pins 1 through 4), the digital inputs (pins 10 and 11) and the digital outputs (pins 7 and 8) can be grouped in one cable.
- these three(3) cables would meet at the DB15 connectors at each end
- the individual cables mentioned above should be shielded for the type of noise expected in the local environment
- grounding for the cable shield would be at the control cabinet end only
- use 24-28 AWG wire within each cable depending on the cable length.

3.4.1.2. Power and RS232 connections

The power and RS232 connections are shown in [FIGURE 3-6]. The power supply supplies the ±12V sensor power. The sensor electronics are electrically isolated from the metal case. It is recommended to connect the power supply 0V to the safety or earth ground.

The RS232 connections should be terminated in the DB9 female connector as shown to allow a direct connection to a standard PC com. port. Note that the signal names at the DB9F connector are referenced to the PC. The sensor's TXD is connected to the PC's RXD and the sensor's RXD is connected to the PC's TXD.

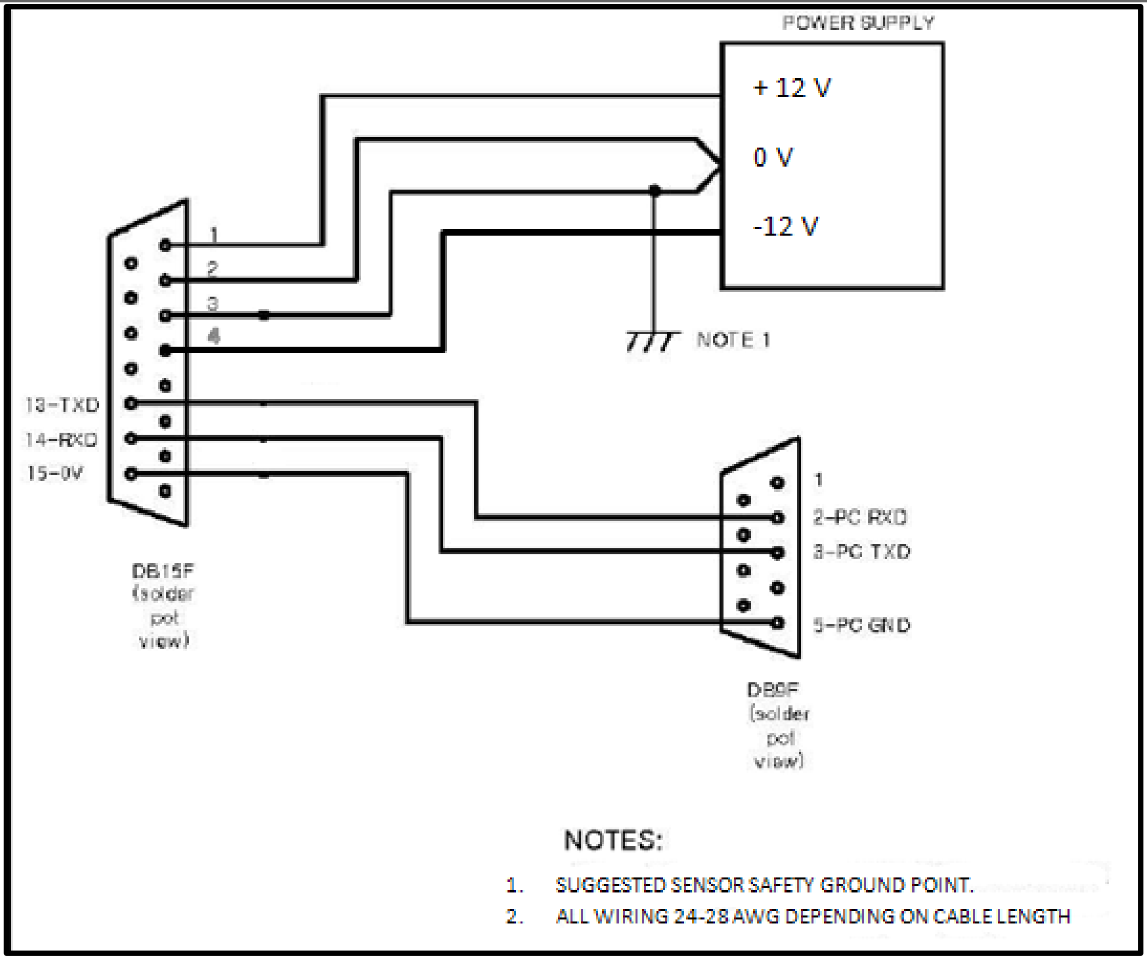

Figure 3-6 Power and RS232 connection

3.4.1.3. Digital Inputs

There are two digital inputs associated with the ATF6 sensor; ***Laser enable*** (pin 10) and ***Camera sync*** (pin 11).

The ***Laser enable*** input is designed to be used as the laser safety interlock. If the signal is not applied to the ***Laser enable*** control input, the sensor's laser is turned off, the sensor's operation is suspended and all outputs (analog, RS232, in-focus and material in view) are set to 0 or negated.

The ON/OFF and OFF/ON transition time is approximately 1 µs.

The ***Laser enable*** input must have an applied voltage greater than 3V for the laser to turn on. If this input is left unconnected or connected to a voltage less than 1V, the laser will not turn on.

warning: Figure shows two methods of configuring the laser enable input. The laser enable switch is shown as a mechanical switch as this is the preferred approach by the safety agencies. The first circuit (CLOSE TO ACTIVATE) is preferred as this is a fail-safe approach if the interlock circuit (i.e. switch and associated wiring) is inadvertently disconnected.

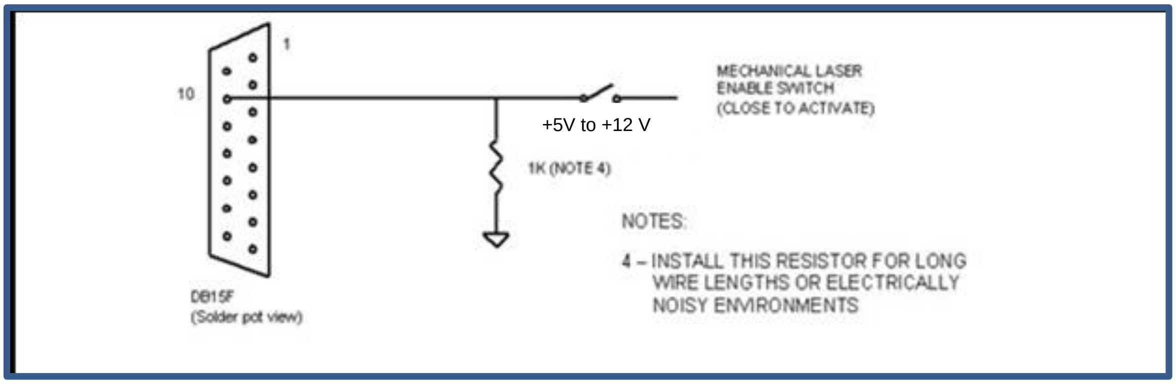

Figure 3-7 Laser enable switch

Camera sync allows turning off the sensor's laser during the CCD camera integration time and turning it back on during the camera data transfer period. Synchronizing the sensor with the CCD camera eliminates the red laser dot - projected by the sensor onto the specimen from the CCD images.

While the laser is off, the sensor continues to output the last valid measurement of the distance to focus to assure undisturbed auto-focus servo operation.

The ON/OFF and OFF/ON transition time is approximately 1 µs.

The ***Camera Sync*** signal is active high. High disables the laser.

The preferred method of controlling the camera sync input is shown in [FIGURE 3-8]. If the camera sync input is not used, it should be shorted to ground.

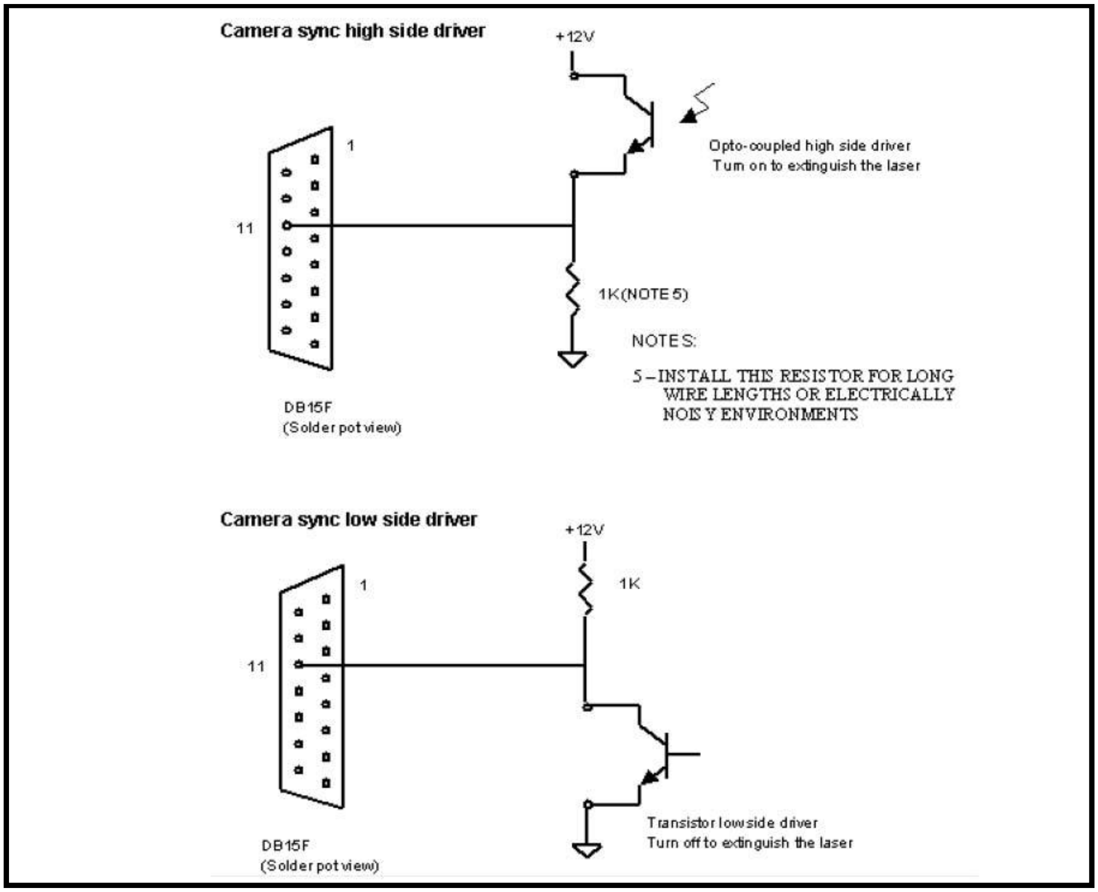

Figure 3-8 Camera Sync Input

3.4.1.4. Digital Outputs

There are two digital outputs; ***In Capture Range*** (pin 7) and In focus (pin 8). ***In Capture Range*** indicates when material is present but not necessarily in focus. ***In Focus*** is asserted when the sensor detects an In-focus condition.

NOTE:

This ***In Focus*** signal should not be relied on before different objectives are programmed into the sensor's memory and configured. Also this signal cannot be relied upon after the objective lens has been changed, until the controller informs the sensor over the RS232 link about the currently used objective.

The default values for asserting the ***In Focus*** bit are factory pre-set for the following ranges around best the focus position (expressed in ±µm):

Table 3-3 default range setting for In Focus bit

Magnification	µm Count
5x	17.54
10x	4.35
20x	1.49
50x	0.53
100x	0.26

These settings are configurable parameters. Both of these digital outputs are negated when the laser is turned off (i.e. the laser enable digital input is negated). They are open collector outputs that are driven low (i.e. to 0V) when asserted. Typically, they would be connected to high side loads.

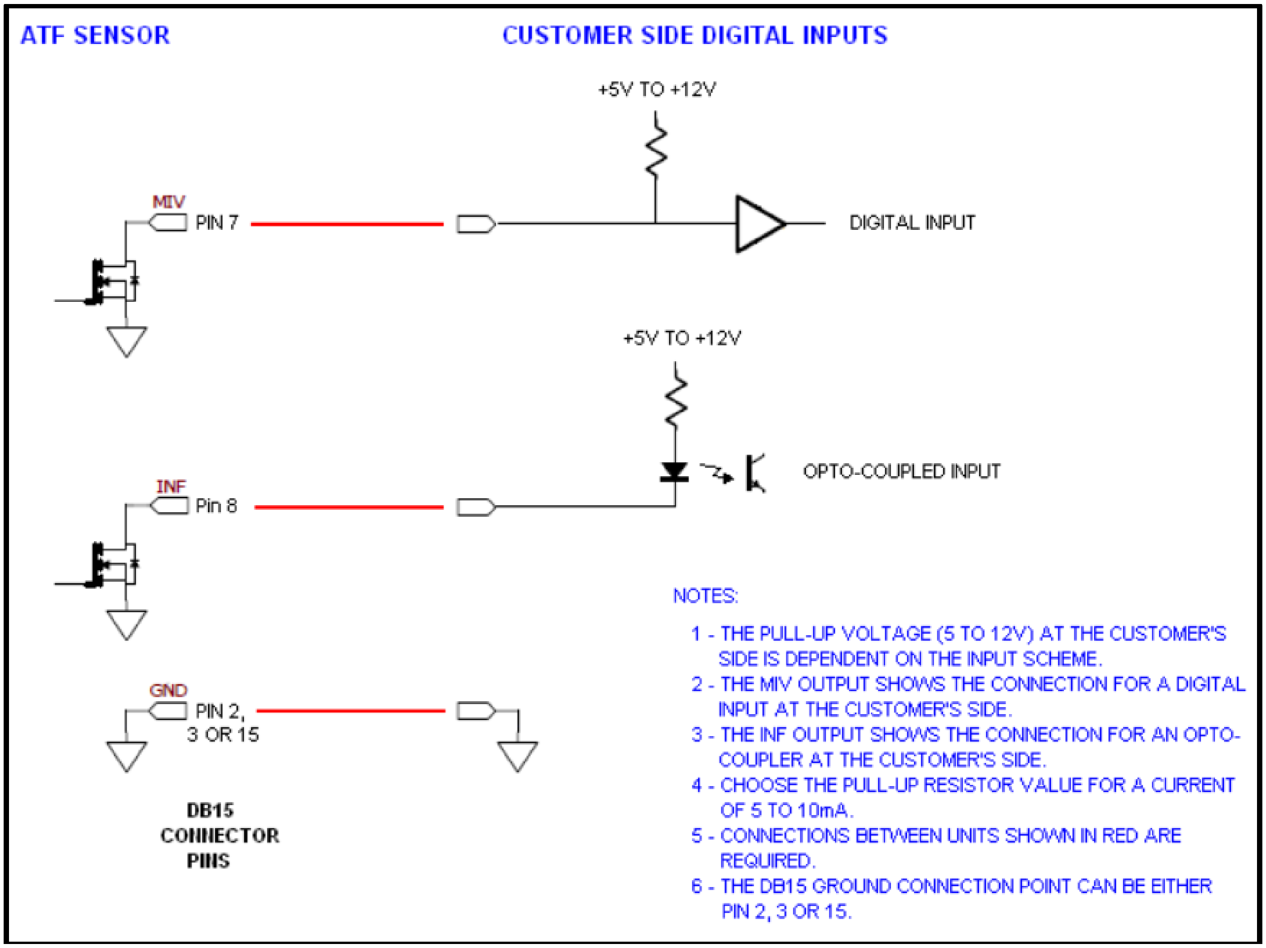

Figure 3-9 ATF Digital Inputs (Typical Connection)

3.4.1.5. Analog Output Connections

The analog output characteristics are summarized in table [TABLE 3-4]

Zero volts indicate in focus position.

Table 3-4 Analog output characteristic

Description	Value	Units
Output voltage range	±8	[V]
Resolution	512	[± counts]
Voltage resolution	5.86	[mV/count]

The resolution in the "Z" direction varies depending on the objective lens magnification as shown in Table 3-6

Table 3-5 default resolution in Z

Magnification	µm per Count
5x	1.40
10x	0.35
20x	0.12
50x	0.06
100x	0.04

The analog output provides a ±8V output range (0V being focused) for distance to focus indication. Two pins are associated with the analog output. Pin 5 is the analog voltage. Pin 6 is a 0V reference from the sensor. The voltage measured differentially across a minimum 2K input impedance analog to digital converter (ADC) or equivalent.

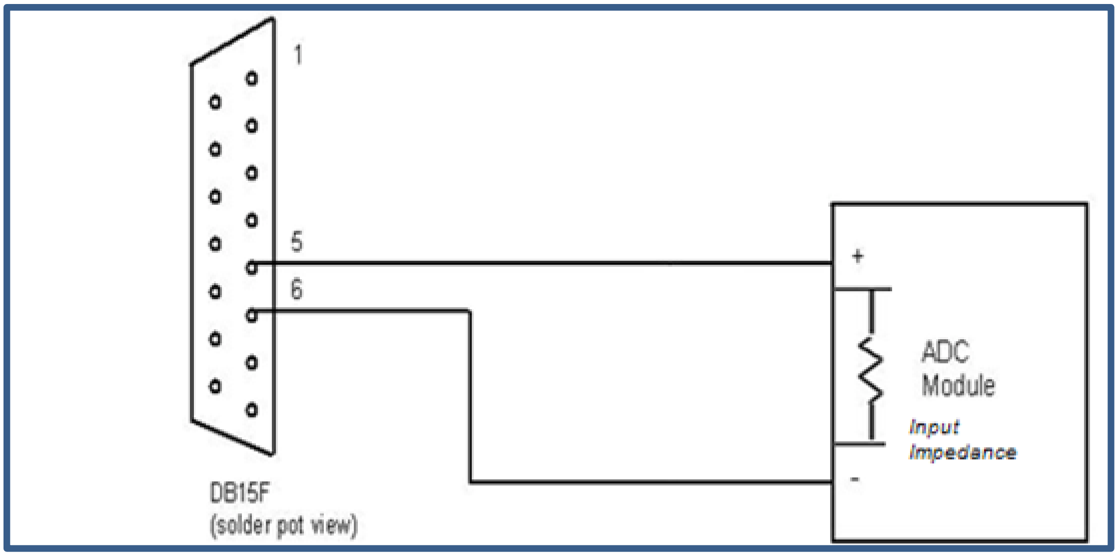

Figure 3-9 Analog output connections

3.4.1.6. Using RS232 as the main sensor output

The RS232 serial port is provided for the sensor setup, reading the sensor measurement values and accessing sensor status reports. Similar to the analog output, the range of reported positional values over RS232 port is ±512 counts. Zero counts indicate best In focus position. The resolution along the "Z" axis is the same as for the analog output on [TABLE 3-4].

The method of connecting the sensor to operate in RS232 mode is shown in [FIGURE 3-6]. This diagram shows the power and RS232 connection.

3.4.2 ELECTRICAL INTERFACE FOR ATF6 SYS Sensor with MCM+/MCZ Controller

The ATF6 with integrated controller constitutes an autonomous servo system. The following functions can be performed by the servo controller in response to the user's commands sent over the RS232 communication link:

- auto focus
- move up or down (a specified number of micrometers/steps)
- initialize "Z" position by homing sequence and track absolute position

○

3.4.2.1. *Interfacing the ATF6 with the integrated servo controller*

The Motor Control Module+ (MCM+) is used with the ATF6 sensor to provide a highly integrated camera focusing system. The only other components required are a stepper-motor drive, stage stepper-motor and limit switches -in Figure 3-10.

The MCM+ signal inputs and outputs have been designed for ease of use when interconnecting the various components. The input and output electrical schemes are detailed below.

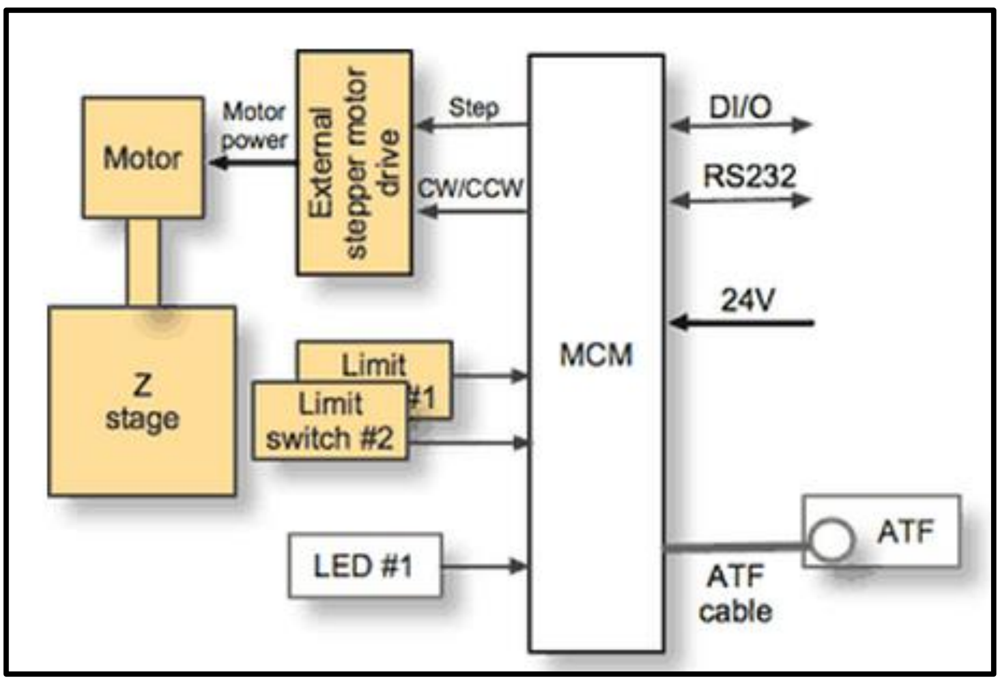

Figure 3-10 MCM+ General System Configuration

80 Gough Rd. Unit 1 • Markham, On, L3R 6E8 • Canada
Phone +1 (905) 415-2734 • www.wdidevice.com

The MCM+ is intended to be mounted close to the ATF6 sensor and the motor drive. The connectors on the MCM+ are designed to reduce cabling to a minimum.

The following is a list of the connectors and their functionality:

1. Power +/- 24V for motor and sensor power. This input is internally fused with a 2.5A slow blow fuse.
2. Sensor – connects to the ATF6 sensor Digital I/O
   - Digital inputs for laser enable, camera sync and motion inhibit
   - Digital outputs for material in view and in focus indication
3. RS232 used to connect to a PC for configuring the sensor
4. Motor power – 24V for the motor drive
5. Motor drive signals – pulse and direction outputs
6. X and Y encoder inputs for MA-AF (if applicable)
7. Limit switches – individual CW and CCW limit switch inputs
8. LED illumination – an output that controls a led for camera illumination

WDI also offers the MCZ controller, which covers all the functionality of the MCM+ and additionally has a built in 2 phase stepper motor drive capable of supplying up to 1.25 Amp per phase.

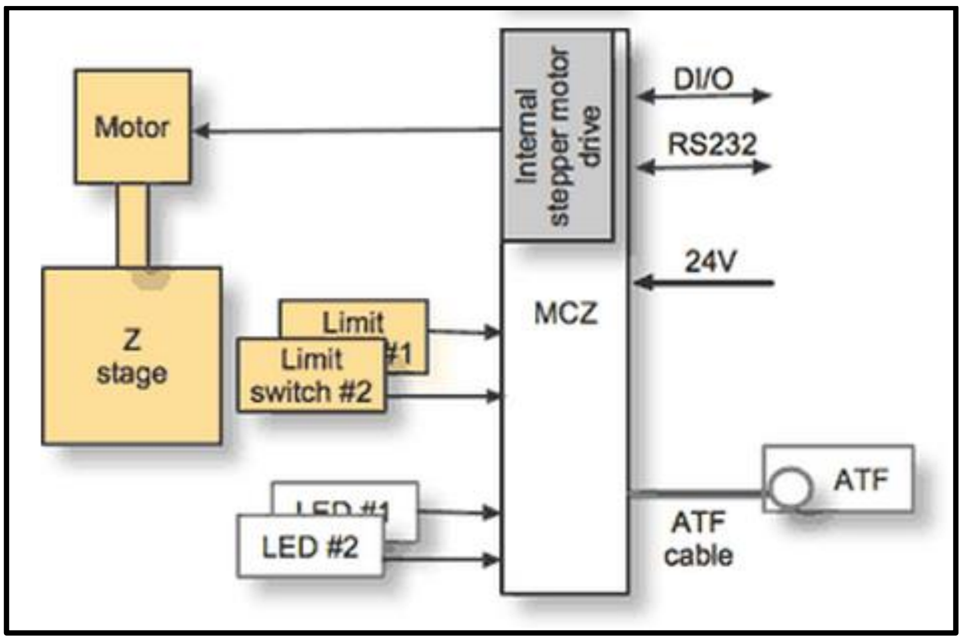

Figure 3-11 MCZ General System Configuration

3.4.2.2. Digital Outputs

Each digital output is an open collector driver capable of sinking 30mA. The maximum load voltage that can be applied is 30V. The applied voltage cannot go negative relative to the motor power ground. For ease of implementation, each digital output has a companion connector pin that is connected to +12V through a 620 ohm resistor. This allows a connection to an opto-coupler input directly while supplying 20mA drive current. The digital outputs will sink current when the corresponding condition is logically true.

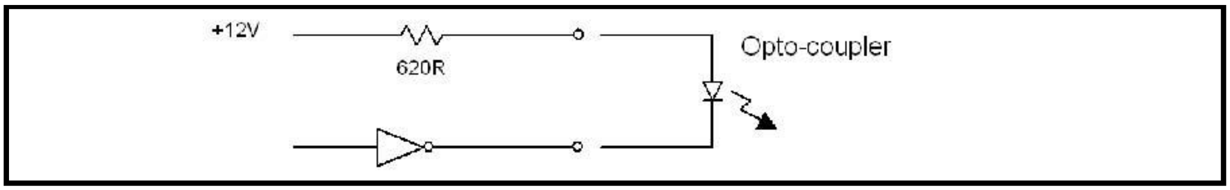

Figure 3-11 Digital outputs (typical connection)

3.4.2.3. Digital Inputs

Digital inputs are receivers that must have an input voltage greater than 3V when asserted. The input voltage range is –12V to +12V. For ease of implementation, each digital input has a companion connector pin that is connected to +12V through a 620 ohm resistor which allows a direct connection to an opto-coupler output or dry relay.

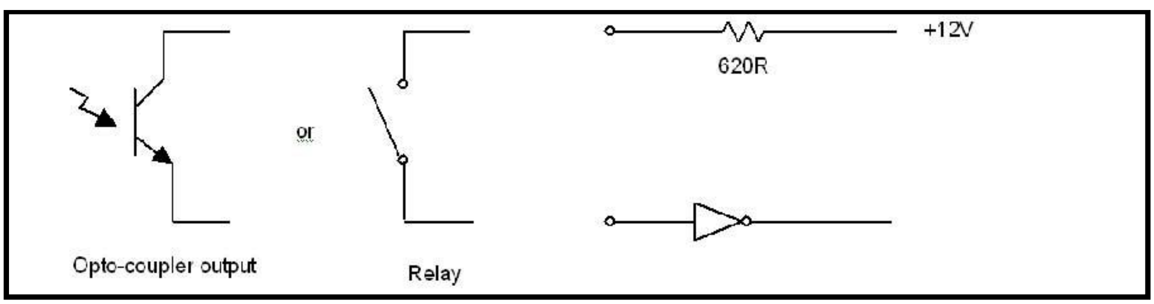

Figure 3-12 Digital Inputs

3.4.2.4. Limit sensors

The CW and CCW limit switch connectors provide pins for +24V, the limit switch output and 0V. These inputs are intended for a high side limit switch that sources current when not triggered, such as the Omron EE-SX47xP series.

For an implementation which would detect a disconnected limit switch, it is recommended that the limit switch sources current while the switch is not tripped.

3.4.2.5. Motor Drive Signals

The motor drive outputs are identical to the digital outputs except that the companion connector pin is connected to +5V through a 100 ohm resistor.

The motor drive input is identical to the digital input.

3.4.2.6. MCM+ and ATF6SYS Connector Signals

The connectors are located at both ends of the box. The following table lists the connector, pin number, signal name and functionality.

Table 3-6 MCM+ Connector Signals

Connector	Pin	Signal	Function
+24V Power	1	24V	- sensor and motor drive power - internally fused at 2.5A, slow blow
	2	0V	- must be connected to protective earth at power supply end
Sensor	1-8		- ATF6 sensor cable signals
Digital I/O	1	+12V	- power for laser enable input (620R resistor)
	2	E stop	- digital input - safety signal which must be asserted for the laser to turn on
	3	+12V	- power for sync input (1K50 resistor)
	4	C-Sync	- digital input - disables the ATF6 Sensor laser while the camera acquires an image
	5	+5V	- power for motion inhibit input (249R resistor)
	6	Motion inhibit	- digital input - safety signal which stops the motor from moving (e-stop) when not asserted
	7	+5V	- power for the led enable input (249R resistor)
	8	In Focus	- digital output - indicates the ATF6 sensor is in focus (active low)
RS232	2	TxD	- RS232 output - MCZ transmit data to the computer - connect to pin 2 of the PC DB9 comm port
	3	RXD	- RS232 input - MCZ receive data from the computer - connect to pin 3 of the PC DB9 comm port
	5	RS232 ground	- RS232 ground - connect to pin 5 of the PC DB9 comm port

Z Drive Control	1	+0V	- stepper motor phase cable shield - do not terminate the shield at the motor end
	2	A+ Phase	- stepper motor phase wiring
	3	A- Phase	
	4	B+ Phase	
	5	B- Phase	
CW limit switch	1	+5V	-CW limit switch power
	2	CW limit switch	-CW limit switch output
	3	0V	-CW limit switch ground
CCW limit switch	1	+5V	-CCW limit switch power
	2	CCW limit switch	-CCW limit switch output
	3	0V	-CCW limit switch ground
LED0	1	V+	- LED illuminator positive voltage (anode) - currently not implemented
	2	V-	- LED illuminator negative voltage (cathode) - currently not implemented
LED1	1	V+	- LED illuminator positive voltage (anode) - currently not implemented
	2	V-	- LED illuminator negative voltage (cathode) - currently not implemented

The following illustration, [FIGURE 3-13] shows the connectors' configuration on MCM+ end plates.

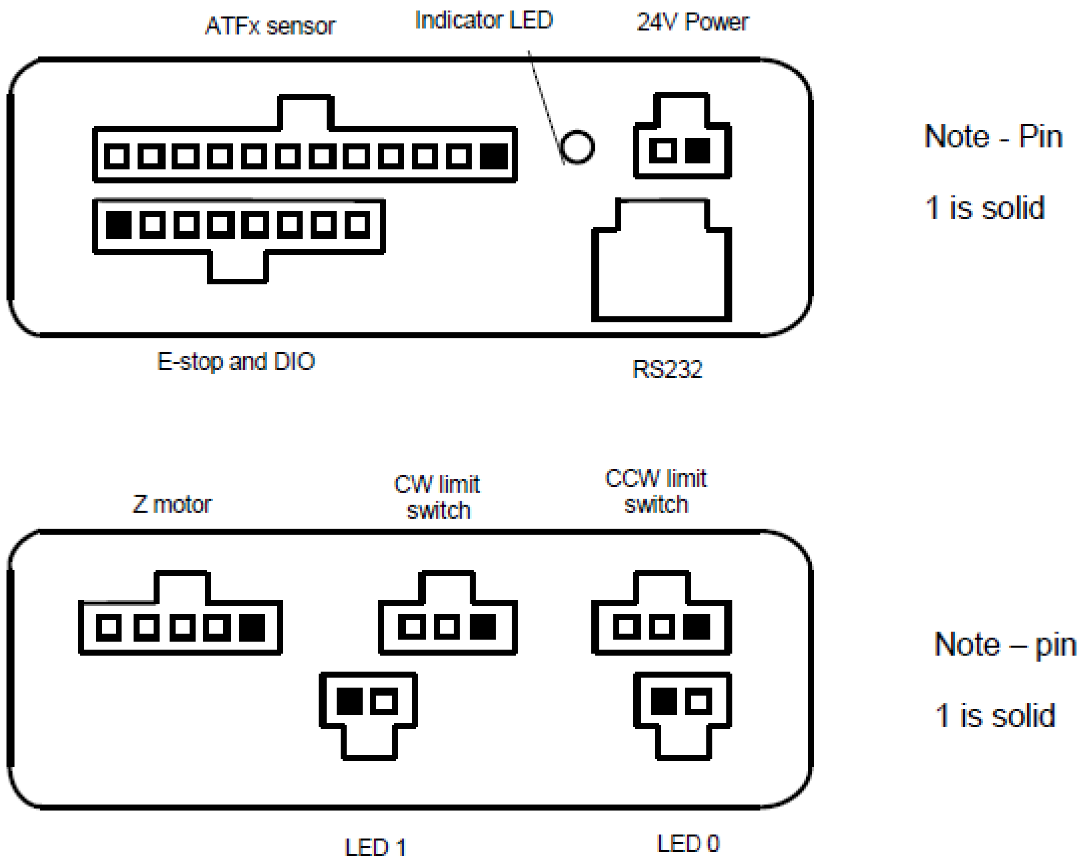

Figure 3-13 ATF6 Connector Location

The MCM+ uses the Molex/Waldom 3mm series of connectors. The plug consists of housing and crimp pins. The part numbers of the various components are

Table 3-7 Component and part numbers

Component	Part Number
2 position plug housing	Molex p/n 43645-0200
3 position plug housing	Molex p/n 43645-0300
5 position plug housing	Molex p/n 43645-0500
5 position plug housing	Molex p/n 43645-1000
12 position plug housing	Molex p/n 43645-1200
crimp pin, 20-24AWG wire	Molex p/n 43030-0009
crimp pin, 26-30AWG wire	Molex p/n 43030-0012
crimping tool	Molex p/n 63811-2800

3.4.2.7. Indicator LEDs

Sensor End - at the power connector end is a green LED which illuminates when 24V power is supplied. Note that this LED will be off if the internal fuse is blown.

Motor End - at the motor end is a flashing yellow LED which indicates that the sensor is connected and has started operating. The flash rate with a standard MCM+ is 0.5 sec - ON and 0.75 sec - OFF. The flash rate with MA-AF MCM+ is 0.25 sec ON and 0.5 sec OFF.

3.4.2.8. Cables

The MCM+ is supplied with a ATF6 sensor cable and an RS232 cable. The other cabling is implementation specific and must be supplied by the user.

The maximum cable length of the ATF6 cable is 6 feet (1.8 m).

The RS232 is 1.8 m long and will directly connect to a standard serial COM port on a PC. For longer cable lengths, use of a DB9 extension cable is necessary. An extension cable has a DB9 male connector on one end and a DB9 female connector on the other end. The wiring is one to one.

3.4.2.9. Operation

Motion is stopped when the motion inhibit input is open or when a limit switch is open and motion is in the limit switch direction. The motion inhibits and limit switch inputs are passive and must be pulled high to operate. Without any motion inhibits or limit switches connected, the motor will not move.

NOTE:
The laser enable input is also a passive input and must be pulled high for the laser to turn on.

3.4.2.10. Configuration

It is highly recommended to use the ***ATF6_Test*** software for the initial system integration. The software provides a convenient, intuitive user interface to all the major functions of the auto focus system as well as an extensive suite of system diagnostics.

Please refer to 0 for the detailed ***ATF6_Test*** software description.

3.4.3 SENSOR'S LED INDICATORS

The sensor has four LEDs that identify the following:

- **Heart beat from fpga**

  This LED blinks at 0.5sec period (approximately). It indicates that the firmware is loaded and operational.

- **Material in View present (In Range)**

  This LED lights when the material is in view (or in capture range).

- **In Focus**

  This LED lights when the microscope is in focus.

  It also blinks during boot time.

- **Communication indicator**

  This LED blinks when: serial communication is exchanged, eprom is written/erased and during boot time

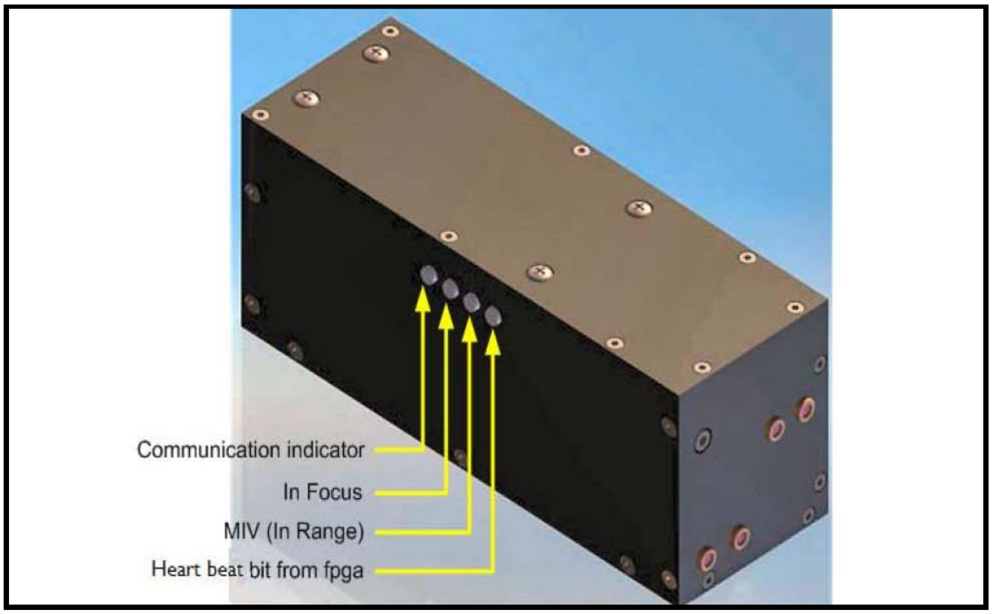

Figure 3-14 LED Indicators on the Sensor

NOTE:
By default, the LEDs light up upon the sensor power-up and then are deactivated by the S/W not to contribute to the stray light inside the equipment.

The LEDs may be configured to stay active at all times at the special request.

3.5. SENSOR SOFTWARE INTERFACES

This section discuses software integration with the ATF6 sensor and host system. The meaning of control parameters is explained, and samples of control sequences show additional details. For the summary of all commands refer to [0].

3.5.1 MODES OF OPERATIONS

ATF6 sensor can operate in combination of one or more operating modes. This section summarizes modes and explains their impact on functionality.

3.5.1.1. AF measuring mode (ON by default)

AF measuring mode activates the sensor algorithms that extract position information from the image signature. This mode is enabled after sensor power up, unless the boot verification discovered hardware errors or unexpected conditions in software, such as the lack of proper parameters being set up. These adverse conditions are indicated by clearing ***SwOK*** and/or ***HwOK*** status bit. Use the U20 command to read the status. The presence of AF measuring mode is indicated with AF Enable flag in U20.

In AF measuring mode, the sensor produces position measurement that reflects the distance from best focus scaled as -512 to 511 a 10bit number over a whole linear range. This value can be obtained with the U41 command and its short equivalent 0x85 data request. The equivalent value could also be obtain as an analog sensor output at Pins 5, 6 (see Table 3-3 for Analog Signal)

In addition the sensor posts status indicators:

InCaptureRange (material in view – miv)

Indicates that the sensor detects the presence of material. This information is obtained from the image distribution across the image sensor. Eliminating stray light reflection during sensor alignment is an important factor in increasing miv range.

InCaptureRange is delivered as:

a) bit 0 in 0x85 command,

b) bit MsMiv in U20 command,

c) Pin 10, See Table 3-7, If SYS is used.

d) Pin 7, See Table 3-3 if ATF6 SA is used.

InFocus

Indicates that the sensor reports position within the 'In Focus Range' from the best focus. In practise, this should be configured to correspond to an acceptable focus condition. The 'In Focus Range' is expressed in internal CCD pixel count and can be accessed with the U53 command.

InFocus can be obtained at:

a) bit 1 in 0x85 command,

b) bit InFocus in U20 command

c) Pin 12 see Table 3-7, if ATF6 SYS is used.

d) Pin 8, See Table 3-3 if ATF6SA is used.

SyncOn

Indicates that sync mode is enabled. See section 0 below. Sync can be obtained as:

a) bit 2 in 0x85 command

b) bit SyncOn in U20 command

LaserOn

Is asserted when laser is turned on. Flag can be read as:

a) bit 3 in 0x85 command

b) bit LaserOn in U20 command

The ***ATF6_Test*** software reports position information as depicted on [FIGURE

3-15] below.

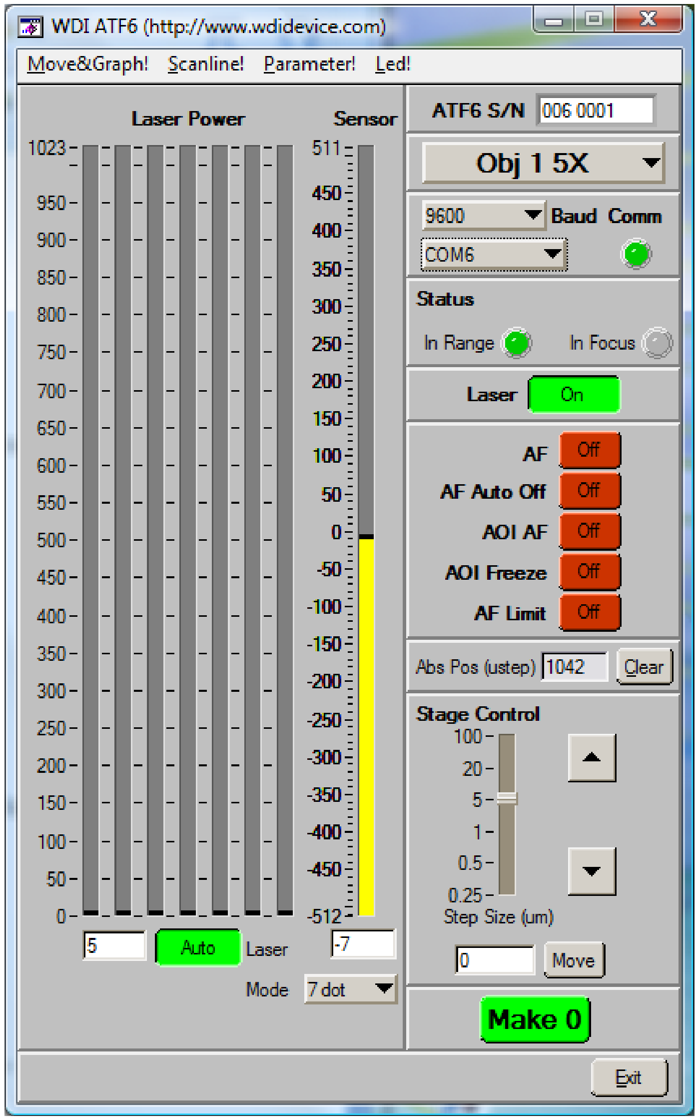

Figure 3-15 ATF_Test main window

The status indicators are presented below on [FIGURE 3-16].

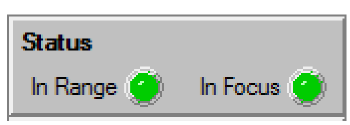

Figure 3-16 Status

The "AF measuring mode" under normal condition remains on. (For testing and calibration purposes, it can be disabled with t7 command and re-enabled with t6 or reboot). In AF mode the sensor reports operation condition of most recent measurement and it can be access with the U42 command. Valid codes are:

I. ***AFStatusOK*** – reports successful measurement is extracted

II. ***AFStatusFailed*** – indicates internal calculation error, should not be reported under normal circumstances. Is indicative of lack of proper calibration, missing parameters or other unexpected conditions.

III. ***AFStatusGlassOut*** – reported when sensor is not able to reliably detect presence of the substrate and calculate the focus position. This status implies ***InCaptureRange*** status being clear.

IV. ***AfStatusNotAvailable*** – reports that measurement data is temporarily unavailable. This flag can be set if surface reflectivity value abruptly changes (e.g. the laser illuminated spot moves from ITO to metal trace). Sensor will automatically correct the laser power (if in "Laser power tracking mode") to restore the proper illumination levels. The position reported by a sensor is going to stay unchanged. Under normal circumstances, the sensor power will adapt within 1-2 measurement cycles and the position measurement will be resumed.

Internally focus measurement reports departure from signature peak position formed on the CCD linear sensor from the zero position. Adjusting the sensor zero position to coincide with the image best focus is therefore very significant. The zero position should be set with U62 command while image remains in focus.

The position measurement reports 0 at best focus and 'Max Position Output' (U61) at the end of the linear range at the distance set by 'Linear Range' (U52). Both of those parameters can be adjusted if needed.

The 'Processing Range' (U54) parameter decides the amount of CCD pixels used to generate the calculation. Do not change this parameter unless there are specific circumstances (back reflection entering the sensor that must be eliminated).

In AF measuring mode sensor automatically decides which of the window acquisition modes should be performed depending on available signal returned from the specimen and distance to best focus position. While at a far distance and within capture range the "Far Mode" is used. Closer to focus the "Central" mode is used, while approaching focus position the "Left/Right" mode is entered. For diagnostic purposes user has an option to override automatic window acquisition selection. Using ***ATF6_Test*** this can be accomplished with "Window Mode" selection available at Scanline panel [FIGURE 4-9].

3.5.1.2. AF and AF Track Mode. (OFF - default)

In both AF and AF track mode, the ATF6 sensor will close the AF loop and attempt to move the Z stage towards the best focus position. This mode should only be turned on when all configuration parameters as listed in section 7.5.4& 7.5.4.2 are provided and sensor is positioned at a “within capture range” distance from the material. The “AF measuring mode” needs to be activated prior to this mode, which typically happens automatically at the end of the boot-up procedure.

This mode requires the “Laser power tracking mode” (auto laser control, default = on) and the “AF” or “AF track” to be ON. If the “Laser disable mode” is going to be entered, ATF6 will abort the “AF/AF track mode”. If the “Sync mode” is going to be entered, the AF/AF track will be suspended until the sync condition is cleared.

The quality of sensor tracking during the “AF mode” depends on multiple factors, which will be explained subsequently.

The user can turn the “AF mode” ON using the U6 command and turn it OFF with the U7 command. If the currently selected lens is DUV, U8 command is used to focus and jump. The AF stops after the jump and it is not necessary to turn off AF in DUV lens case.

The “AF mode” has a “AF Fast Z tracking mode” variant, or “AF track”. This mode is entered using U9 command. The “AF Fast Z tracking mode” is designed to allow fastest sensor operation w/o cumulating errors - a mode designed to track glass height variations while objective moves along glass surface. This mode is particularly useful for objectives 10, 20, 50 in AOI (scanning) applications. If the object is stationary, using AF track is not recommended. The AF track mode uses only the central three laser spots (more bad spot effect) and may vibrate. Turning off “AF track” command is same as “AF” (U7).

To enter the “AF” or “AF track “mode using ***ATF6_Test***, press corresponding button shown in [FIGURE 3-17].

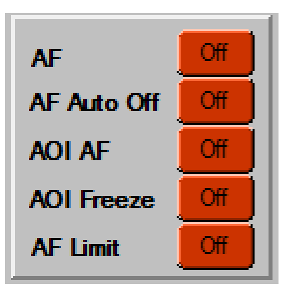

Figure 3-17 Auto Focus button

AF mode is indicated by ***ZTracking*** bit that can be read with U20 command.

The "AF Auto off" option (See [FIGURE 3-17]) allows turning off automatically "AF" mode and laser power once focus is reached. This option has no effect on "AOI AF" mode. It can be enabled by setting bit 2 (0x4) at CustomerOption[1] configuration byte. If disabling "AF" mode automatically once in focus range is desired (no effect on laser) then U8 (instead of U6) should be used.

The "AF Limit" variant of the "AOI AF" and "AF" modes allows placing limitation on the Z movement during Z tracking. The limitations are defined in subsequent window if ***ATF6_Test*** is used. See figure below.

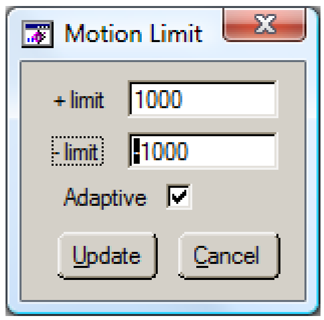

Figure 3-18 Motion Limit definitions

The +-limit specifies number of micrometers that Z motion is allow departing during tracking from the starting Z position, which is Z position at the time "AF tracking" mode was engaged. ATF6 sensor will no longer correct Z position that exceeds the limit band, but will track Z as soon as Z returns back into +-limit range. This feature is helpful when trying to avoid extraneous motions outside of glass substrate. The "Adaptive" option allows for the slow starting Z position creep that would happen if glass substrate is slanted or otherwise not flat. Motion Limits are specified with U112[3] parameter that affect only the subsequent U6,U8,U9 commands.

It is important to turn "AF" mode OFF in circumstances where sensor is not able to reach a focus position and might cause undesired stage Z motion. Such a situation include: objective change and absence of a material.

3.5.1.3. Laser Disable Mode (OFF by default)

In this mode laser diode current is shut down and no illumination is generated. This mode excludes AF Z tracking. Laser disable mode is intended for situation when laser illuminated line is not desired on the image, emergency laser shutdown, or system maintenance.

Upon system start-up if no error conditions are detected ATF6 will automatically activate laser turning “Laser disable mode” OFF. This mode is controlled by software commands U1 to enable laser and U2 to disable it. The same effect is achieved by asserting digital input Pin 2 (See Table 3-7) to activate laser and clearing it to turn laser off.

Entering “Laser disable mode” pre-empts all other modes leaving sensor in initial state.

The “Laser disable mode” can be controlled using ***ATF6_Test*** software by pressing ‘Laser’ button, as per **[FIGURE 3-19]**.

Figure 3-19 Laser button

“Laser disable mode” is indicated by ***LaserDisabledMode*** bit that can be read with U20 command.

3.5.1.4. Sync mode (OFF by default)

“Sync mode” is designed to temporary turn off laser illumination for a short period of time. The intended use is to allow image acquisition to take place w/o ATF6 red laser illumination spot visible on the image. During the time that sync condition last laser stays off and sensor suspends AF processing maintaining same position result and not executing AF Z tracking. If tracking AF is required with moving payload using “Sync mode” is going to negatively affect speed of Z tracking proportionally to the time ratio “Sync mode” is ON.

“Sync mode” can be controlled from software by sending U3 command to set sync condition ON and U4 to clear it. Same result are accomplished by asserting digital input Pin 4 2 see Table 3-7 to set sync ON and clearing it to set it OFF.

“Sync mode” is indicated by ***SyncOn*** bit that can be read with U20 command.

3.5.1.5. Laser power tracking mode (ON by default)

In this mode, the ATF6 sensor regulates the laser power with every image acquisition in order to maintain signal level within accepted corridor that permits accurate position measurements. The Signal level depends on multiple factors: distance from focus, surface properties, and system calibration to name a few.

The "Laser power tracking mode" is required for the "AF Z tracking mode" to produce valid results in a wide range of circumstances. Under normal measurement conditions, the laser power tracking mode should be on; this mode is turned off during calibration and maintenance procedures. The laser power value can be read and written with the U30 register. If the laser power tracking mode is on, this value will be adjusted constantly.

For system calibration or system maintenance condition laser power can be adjusted manually. In such case the sensor will report proper measurement only when the laser level is appropriate (U42 returns AF Status OK). The AF Status ***LowIntensity***, ***NotAvailable*** might be reported if the laser illumination condition is not accepted by the sensor algorithms.

"Laser power tracking mode" can be entered with the t6 command and exit with the t7 command. Using ***ATF6_Test*** software, this mode can be controlled by changing the 'Laser Control' settings [FIGURE 3-20].

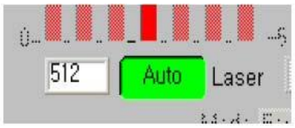

Figure 3-20 Laser Control Setting

"Laser power tracking mode" is indicated by Ms Laser Tracking bit, which can be read with the U20 command.

3.5.1.6. Z Motion

The ATF6 sensor actuates the Z stage position driven by integrated stepper motor controller either in open loop reacting to external command, or in a close loop when motion is schedule to compensate position error, and in effort to bring the stage into the best focus position. In both cases, the same trapezoidal motion profile is generated that can be described by:

Distance in micro steps

Requested motion distance expressed in micro steps can be written using the t100 command while using open loop control. In case of close loop control the t100 can be read to indicate the distance covered in most recent motion.

Maximum motion acceleration

Use 'Max Acceleration' command U107 to specify this parameter for every objective. Typically, the same values are applied to all objectives. Max Acceleration is expressed in um/s. The necessary step to mm conversion is supplied with 'Step Conversion' U100 parameter.

Maximum motion velocity

Use 'Max Velocity' command U108 to specify the stage maximum speed reached on flat trapezoidal profile. Command U108 expresses speed in um/s relaying on U100 'Step Conversion' parameter.

For each objective, a choice of micro stepping could be selected between 2 possible values. Micro stepping parameter U101 provides multiplier expressing number of micro steps corresponding to 1 step. Micro stepping selection U105 is used to assign micro stepping multiplier value for each objective. The resulting distance of motion executed by stage is:

z [mm] = (md / us [us_sel]) / sc ***(i)***

Where:

md= Motion Distance-t100 [microsteps]

us[us_sel]= Microstepping-U101 [microsteps/steps]

us_sel= Microstepping selection –U105

sc= Step Conversion-U100 [steps/mm]

z= Distance of motion [mm]

Based on formula (i) one can calculate value of the of "Step Conversion" parameter:

Stage Conversion [steps/mm] = (md / us [us_sel]) / z ***(ii)***

The motion profile described by the parameters listed above can be characterized on a [FIGURE 3-21].

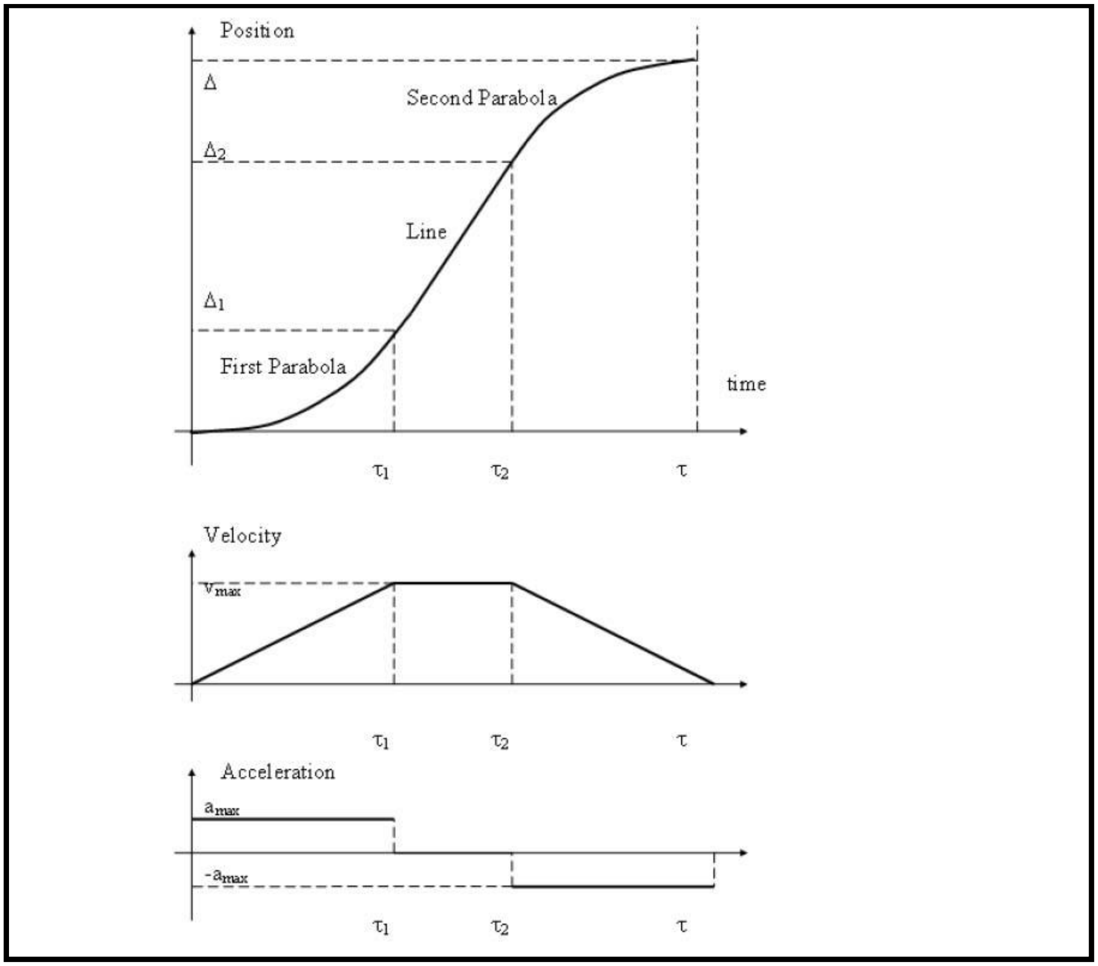

Figure 3-21 Motion profile

Acceleration and Deceleration of the Stepper Motor are represented with parabolic line with the constant speed represented by linear section. If the distance covered is less than necessary to reach a linear section, then the motion profile consists of 2 parabolas only.

As long as there is no slippage of the stepper motor, the cumulative Z position can be regarded as an absolute Z position of the stage. The sensor provides U109 parameter that keeps track of all motions executed since software reboot. This parameter can be reset to 0 at any point if it suits integration with the external host. The sensor updates the U109 value at the end of each motion. The host is therefore required to validate that motion has ended, and only then, able to rely on U109 as accurate reflection of current Z.

As long as the stage executes Z motion, the ***ZMotion*** bit is asserted and can be read with U20 command (or bit 10 in f30/t84 command).

Motion can be inhibited by writing U16 command. This will result with abrupt motion stop. To be able to resume motion after such condition, U15 should be issued. Motion can be inhibited if limit switches are triggered. Limit switches polarity could be reversed with t86 command.

3.5.1.7. AF close loop tracking in linear range

While the sensor measured position falls within linear range in "AF Z tracking mode", the AF tracking algorithms continuously computes correction that is used to drive the stage towards zero position. The AF control principle AF inside the linear range is depicted in [FIGURE 3-22].

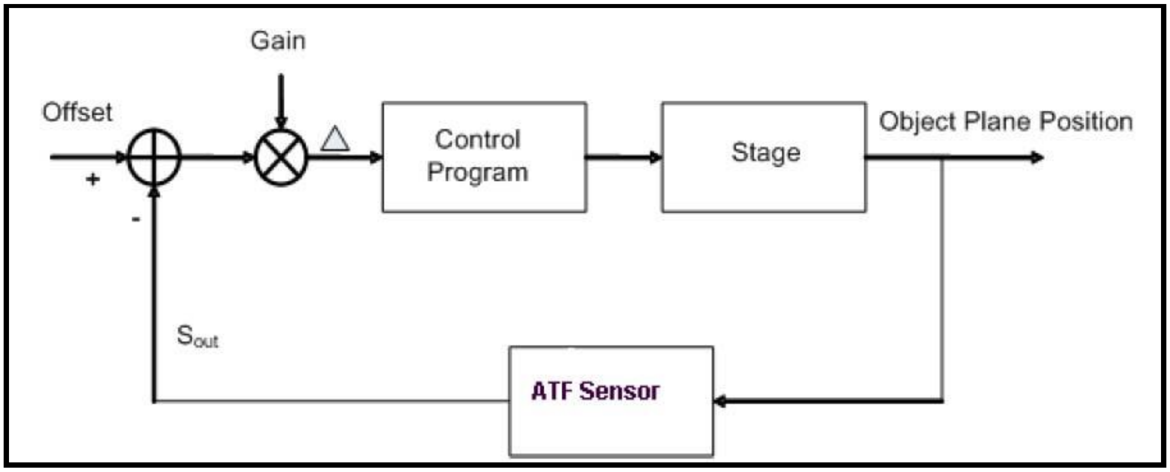

Figure 3-22 Simplified Control Diagram

The control is done using the stepper motor with the 'number of steps to go' as input. The 'number of steps to go' is:

Z = (Offset – AF Sensor Output) * Gain ***(iii)***

Our control sequence is:

1. Calculate the difference between zero offset and the sensor output (sensor position) and multiply this value by gain
2. Send this value to the stepper motor driver and wait until the stepper motor moves the stage at requested distance.
3. Do step 1) until a 'less than predefined value' is reached, Therefore distance to move in mm is calculated as:

z[mm] = - gc * po * oc * 1000 ***(iv)***

where:

gc= GainCoefficient-U106 [1] set for each individual objective

oc= Output Conversion-U55 [um/output]

po= Position out [output]

Or calculating z[micro steps] can be expressed as follow by incorporation of formulae (i):

z [microsteps] = gc * po * oc * 1000 * sc * us [us_sel] (v)

where:

us= Microstepping-U101 [micro steps/steps]

us_sel= Micro stepping selection –U105

sc= Step Conversion-U100 [steps/mm]

gc- GainCoefficient-U106 [1] set for each individual objective

oc- Output Conversion-U55 [?m/output]

po- Position out [output]

The correction distance (v) is expressed in micro steps; it is being rounded off toward closest integer. If it is 0 or lower than half of the "In Focus Range", then no correction is executed, and focus is assumed to be reached.

Formulae (v) states equivalence between various parameters, oc is a system parameter that is the best set experimentally to the required resolution by performing short motion around the zero position.

The ATF6 readings are affected by material type and transitions in the region illuminated by the laser light. In accordance with ATF6 principle of operation, the sensor reports measurements proportional to the shift of reflected light signature signal formed on the sensor light sensitive array. If the area illuminated by the laser features sharp differences in reflectivity due to material borders (exp: metal/ito, via, etc), formation a concave/convex structure with lens-like effect (exp: tempering of thick coating), then some departure from the sensor linearity is expected. See [FIGURE 4-12] for examples of deviation from linearity.

ATF6 sensor projects laser light in a shape of a line. In order for ATF6 sensor measurement to be affected by the surface feature the significant portion of the laser line would need to be affected the same way. If the illuminated line surface consist of random variation then sensor measurements are not affected. The primary cause of systematic deviation of ATF6 measurements is a case when ATF6 line is positioned in parallel with elongated structure. See [FIGURE 3-23].

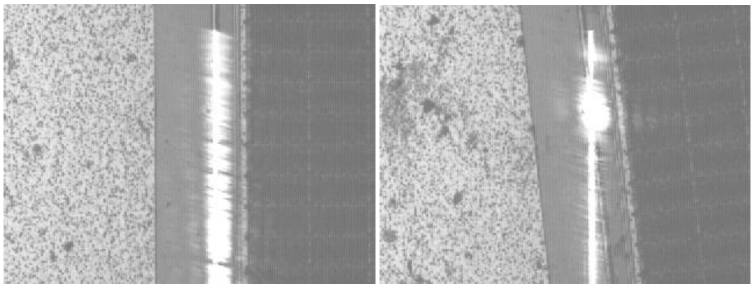

Figure 3-23 Alignment Deviation on Substrate Illuminated Laser Line

The left image will cause deviation due to parallel positioning while the Right image will have precise measurement.

When ATF6 operates in a close loop position measurement errors might result in offset from the best focal plane and/or vibrations.

There are number of ways closed loop vibrations and offsets are being dealt with in ATF6 design:

- The primary way is to try to reduce sensitivity to factors that are causing deviation of characteristics. This can be accomplished by assuring that sensor line crosses at angle > 8deg any elongated features that are present on the substrate. WDI recommends installing sensor at angle 45deg to minimize such a coincidence.
- ATF6 software reduces sensitivity to vibration in number of ways. The primary technique is to rely on number of line segments (up to 7) obtained from different locations. The final result is a digitally filtered position that depends on all available measurements.

3.5.1.8. Close loop tracking outside linear range

In case distance reported by sensor exceeds linear range a simplified algorithm (to the one described in previous section) is used reach a focus: sensor schedules motion equivalent to 'Linear Range' (U52) times Far Gain Coefficient (U106) toward best focus. Such a situation is demonstrated on [FIGURE 3-24] for P0 and P1:

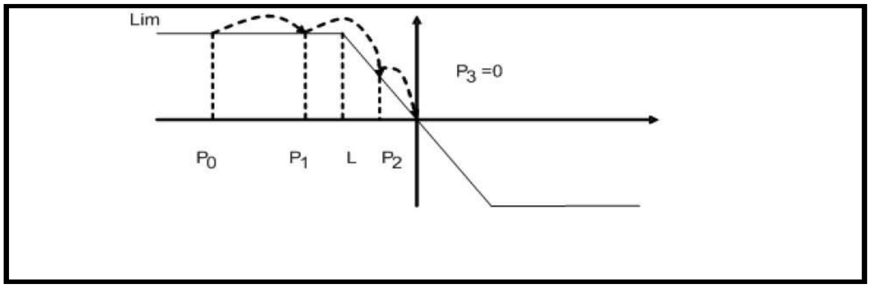

Figure 3-24 Motion outside of sensor linear range

3.5.2 CONFIGURATION COMMANDS REGISTERS REFERENCE

3.5.2.1. User accessible registers

The ***ATF6_Test*** software (described in more details in 0) provides means of accessing most of user parameters [FIGURE 3-25] provides mapping between "ATF6 Parameter" dialog and registers referred to in 7.5.4.2.

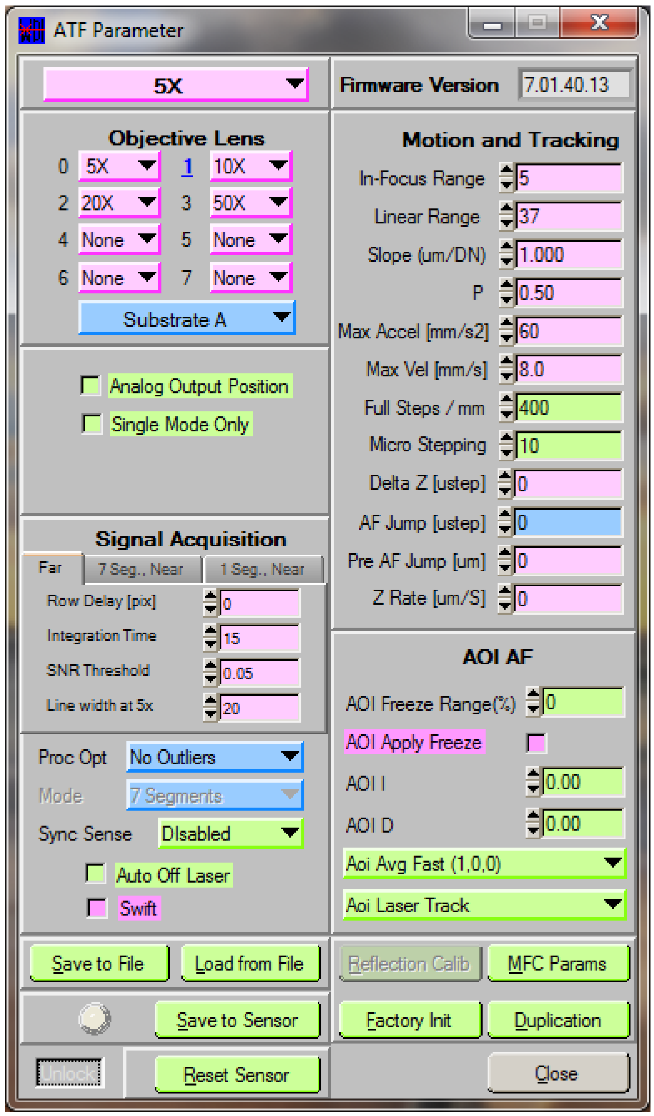

Figure 3-25 ATF6 Parameters available with ATF6_Test

3.5.3 ILLUMINATOR CONTROL

This document describes additional illuminator control feature available with ATF6 sensor software version 6.f or later. Feature can be controlled with ***ATF6_Test*** software which provides access to one LED. Up to 3 LEDs could be controlled by ATF6.

3.5.3.1. Illuminator control

ATF6 permits controlling illumination by specifying pwm value from 0 to 100%. The illumination current can be set from 30 to 800 mA with 10 mA increment. In addition there is digital input provided which could be used to turn illumination ON/OFF from an external device.

The light control window is available with ***ATF6_Test*** software by pressing "LED!" menu option which launches the 'Illumination LED' screen as shown in [FIGURE 3-26].

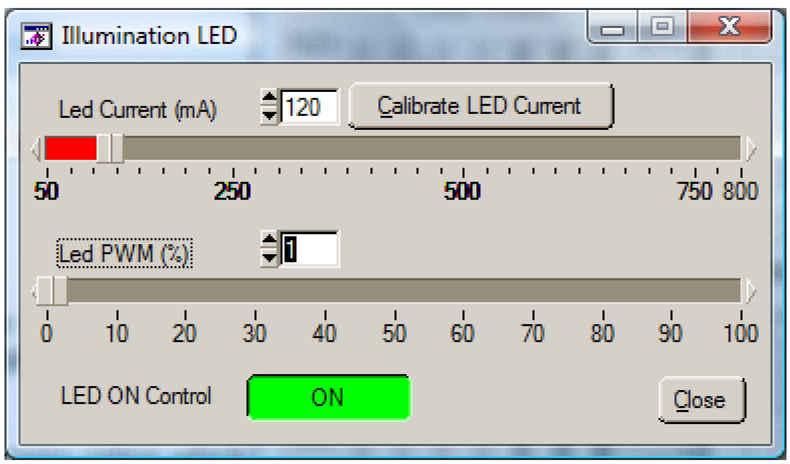

Figure 3-26 Illumination LED

Led Current (mA)

Adjusting 'Led Current (mA)' slider selects the current value that is being sent to ATF6 sensor when 'Calibrate LED Current' is pressed.

Led Pwm

Adjusting 'Led Pwm' immediately controls the light intensity.

3.5.3.2. Configuration Commands Registers Reference

Table 3-8 configuration commands registers

LED Pwm Control	U130[3] (130.85)	1,Word,read, write, signed	Sets LED pwm and enables light. Valid numbers are -100 to 100. If value is 1 to 100 the laser pwm is set and light is turn ON. Value 0 turns LED OFF and sets pwm to 0. Values -1 to -100 sets pwm but turns laser software switch OFF – in order to turn light on, the DIO pin needs to be asserted. This value is not preserved. The array of 3 elements allow to control up to 3 LEDs.
LED current control	t131[3] (116.131)	1,Word,read, write	Programs value of the current driven through the led. Value can be from 3-80, which correspond to 30-800 mA range. Upon sending this command, LED controller will re-calibrate the current control loop for the specified current. Value is preserved in eeprom with U5. Value is loaded at the boot time. The array of 3 elements allow to control up to 3 LEDs.

Chapter 4

SENSOR ALIGNMENT

The careful integration of the sensor with the user's optics is imperative to the proper auto focus system operation. The sensor integration brakes into 3 major steps:

- Sensor alignment versus the optical port
- Sensor adjustment
- Final system integration
- Sensor setup

1. In the first step the sensor is installed on the user's microscope, powered up and the sensor's laser beam is shifted and steered such that the beam properly enters the objective lens and the laser line appears in the centre of the review camera image. The alignment is limited to adjusting the sensor position within its slotted mounting holes and tuning the user provided sensor's beam-splitter and/or camera beam splitter.
2. In the second step the adjustments are made to the sensor's internal optics such that the sensor is adapted to a particular optical setup. The objectives of this alignment step are to adjust the laser line image to be projected precisely on the centre of the sensor's internal photo diode array. Adjusting the laser line image position across the array assures that the sensor receives maximum available optical power resulting in a good SNR; adjusting the laser line image along the array corrects the offset error.
3. The third step is necessary to assure that the best focus position detected and indicated by the sensor is consistent with the review camera best focus. By adopting the ATF6, the user introduces an additional optical path to the microscope: the sensor's optical path. The sensor shares with the user's microscope the objective lens, but uses its own tube lens to form the image of the reference laser dot. The sensor's tube lens is precisely positioned assuring that laser beam emerging from the sensor is collimated in one direction. This assures that the infinity corrected microscope objectives will interact optimally with the sensor. In the third alignment step, the user is required to tune the review channel tube lens position so that the best focal plane of the review camera accurately overlaps with the sensor's best focal plane.
4. The fourth step is to inform and train the sensor for various lenses.

The following chapters detail the alignment procedures for each of the alignment steps.

The alignment procedures are based on the assumption that the user's microscope is well aligned, in particular:

- the microscope objective lens is coaxial with the camera tube lens
- the microscope main optical axis is perpendicular to the object plane and the image plane
- the review camera photo diode array is coaxial with the microscope's main optical axis

4.1. ALIGNMENT VERSUS OPTICAL PORT

The following are the sensor alignments steps:

- Place the sensor into its mount.
- Make sure that the review camera is initially positioned at a distance matching the tube lens focal length. Also, it should be assured that center of the camera image coincides with center of the microscope optical axis.

NOTE:

To verify that camera is set in infinity corrected range, apply the following procedure:

- Change objective to highest available magnification lens (e.g. 50x)
- Find best focus
- Change objective to lowest available magnification lens (e.g. 5x)
- Adjust tube lens to obtain image in focus
- Put the specimen under the microscope's lowest objective lens and bring the microscope to best focus using the review camera image as feedback. Clear glass specimen or a large clear spot on a panel is recommended for sensor alignment.
- Power-up the sensor and start the ***ATF6_Test*** program. At this time please select the Baud rate of 9600 and please remember to choose the appropriate sensor com port for the connection.

Depending whether the microscope objective entry aperture is visible during alignment, align the sensor versus the optical port (sensor beam splitter) using one of the two equivalent procedures:

- Objective's entry aperture IS visible within its assembly. See 4.1.1.

➢ Objective's entry aperture IS NOT visible within its assembly. See 4.1.2.

4.1.1 OBJECTIVE'S ENTRY APERTURE IS VISIBLE WITHIN ITS ASSEMBLY

The laser light shape that is emerging from the sensor is depicted below in [FIGURE 4-1]. The two cases are described:

1. "Above" when beam is observed right by the lens;
2. "Below" when measured at the large distance.

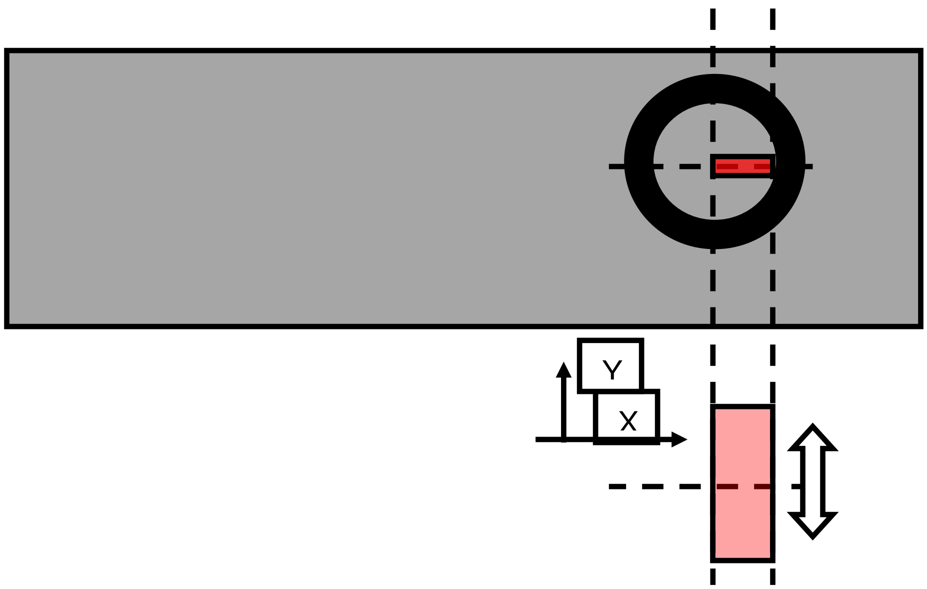

Figure 4-1 ATF6 Sensor Laser Illumination as Leaving Sensor Lens.

The figure above depicts laser shape measured right by the lens, while the figure below corresponds to the measurement done at the distance.

Note:

➢ Laser light shape resembles elongated rectangle that is placed on one side of the aperture and centered along horizontal line (as per picture).

➢ As the distance increases the "height" (along X) of the line remain the same, while the initially narrow "width" (along Y) first decreases to 0 (at the distance of about 150mm) and then increases.

In order to assure the appropriate alignment the ATF6 sensor illumination should enter the objective aperture maintaining the same relative orientation. See [FIGURE 4-2] for details.

Note:

- Laser light rectangular beam "height" is preserved and it fits in the same half of objective aperture.
- The beam is centered with objective horizontal axis (X as presented in the figures) while the "width" might be changed (larger or smaller).

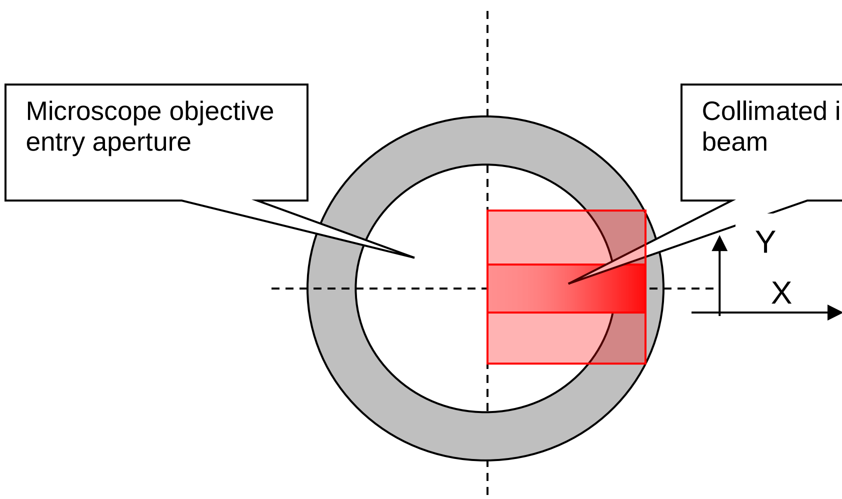

Figure 4-2 Alignment: Laser beam versus the aperture opening

The goal of sensor alignment is to achieve the laser beam entry position as depicted in [FIGURE 4-2] AND assure that laser enters objective orthogonally.

The sensor alignment is accomplished by:

- Assuring that sensor lens is mounted coaxially with microscope.
- By translating the sensor along the elongated slots in mounting plate. This motion shifts sensor beam along X axis as per Figure 4-2.

By adjusting beam splitter kinematic mount [

- Figure 3-4] X,Y adjustment which has a combined effect of shifting the beam in X,Y and also changing the angle..

It is recommended that alignment is done first on lowest objective (e.g. 5x) and then repeated (readjusted) on the highest objective (e.g. 50x or 100x). This stand from the fact that alignment for lowest objective is easiest to do, while highest objectives requires tightest tolerances.

For objective lenses x100 it's +0 mm, -0.3 mm ("+" means that the beam covers more than ½ of the aperture.) +0mm tolerance indicates that the laser should NOT cover more than half of the aperture.

Here is a short description of alignment faults and typical methods of rectifying the problems, see Table 4-1below.

Table 4-1 Alignment problems and typical solutions

	Alignment Problem	Typical solution	Performance implication
1	ATF6 line is shifted along X axis	Loosen the mounting screws and move sensor along elongated slots.	If line is too much shifted to the left (as per [Figure 4-2]) then slope is going to be too shallow, if shifted to the right, then capture range on highest objectives is going to be compromised
2	ATF6 line is not centered as per camera image	**Adjust beam splitter kinematic mount [** Figure 3-4] X,Y	loss of light and reduced capture range due to the losses when some of the returning signal reflected from target misses aperture
3	ATF6 line is shifted along the Y axis	**Adjust beam splitter kinematic mount [** Figure 3-4] X,Y. Also, correct axially of the microscope	For 50x (small aperture) ATF6 illuminated line will move not only along X (left-right as per [Figure 4-3]) but also up-down which will reduce capture range.

Once desired position is accomplished fix the sensor position using mounting screws assuring that it does not shift while mounting screws are being tightened.

NOTE:

There is minimal optical interaction between the laser beam position adjustment versus the microscope objective and the positioning of the laser line on the specimen. If, however, the initial position of the sensor's beam splitter was very inaccurate and the sensor's beam splitter had to be tilted, the alignment procedure may need to be repeated more than once to assure the beam coverage on the objective lens aperture is within specification.

The accuracy and eventually the success of alignment need to be verified and determined with the ATF6_Test software 'Move & Graph' procedure. This procedure is described in the next chapter 4.1.2 below. It is recommended that both low magnification and high magnification 'Move & Graph' are performed in order to numerically verify quality of alignment.

4.1.2 OBJECTIVE'S ENTRY APERTURE IS NOT VISIBLE WITHIN ITS ASSEMBLY

If objective aperture is unaccesable, the alternative adjustment can be made with the help of the system camera.

NOTE:
This method assumes also that microscope objective of 5x,10x or 20x are available with similar NA to standard Mitutoyo objectives.

NOTE:
This procedure requires usage of ***ATF_Test*** software and adjusting Z position. Because of this limitation on ATF6SYS version of the sensor can be aligned this way (not ATF6SA)

With the speciment in focus and camera and ATF6 sensor turned ON follow the steps indicated below:

- ***Mount ATF6 coaxially with the optical input port***. Place ATF6 on the mounting plate and assure that ATF6 lens meets microscope optical port coaxially.
- ***Adjust beam splitter to be at angle 45deg*** as close as feasible.
- ***Bring laser line to the center of camera image***.
- Run ATF6_Test software and connect to the sensor.
- Select the appropriate objective at Parameter menu, see [Figure 3-25])
- Click on laser power button to select "Manual" option [Figure 3-19]. Then set laser power to high value, typically 500. With such a setting you should be able to see the laser line if it is displayed in your camera field of view. (This step assumes that any optical filter that might be placed in front of camera to reject ATF6 laser illumination was temporary removed).

  If you see the line center it with camera FOV by adjusting beam splitter kinematic mount Figure 3-4

If you don't, then you might need to rotate beam splitter significantly.

The helpful trick might be to place a diffuse target (paper ?) and look at it with camera illumination turned off. You should see laser illuminated red specled reflection (you are looking at target under objective, not at camera image!). Then turn on the camera illumination on gradually. Observe the relative shift between ATF6 laser illuminated spot and camara illuminated patch. With the help of kinematic mount/beam splitter rotation you should be able to bring the laser toward center, upon which you should start seeing the line image in your camera view.

- Once ATF6 line is centered, turned back the automated laser power by clicking back to "Auto".

At the end you should be able to see line as depicted on the figure below. You should be able to move stage up and down and observe laser line traversing from left to right (as per figure [Figure 4-3])

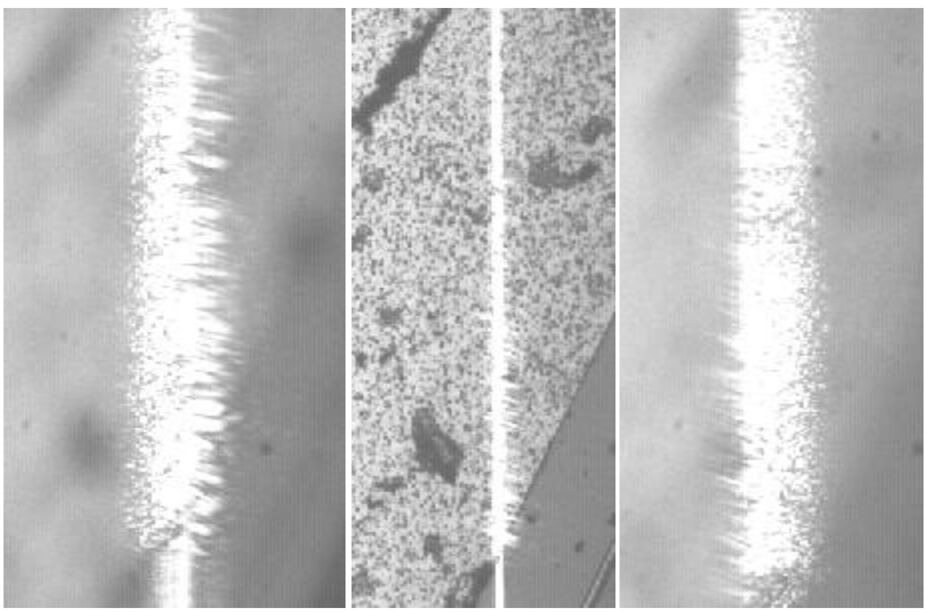

Figure 4-3 Adjusting sensor beam splitter using review camera with magnification 5x.

- The image to the left is below focus, center in focus, right is above focus. The deflection is about 20um.
- ***Adjust sensor shift along X (see [Figure 4-2]) by measuring angle of transient characteristic on low objective (5x)*** with "move&graph".
- With lowest lens (e.g. 5x) selected and sample brought to focus click 'Move & graph" pane of ATF6_Test software.
- Select range +-200um and 5um step.
- Click Go.

- The result should be plotted as a sloped line similiar to the one depicted on [Figure 4-12]. Measure the slope of the line by clicking and placing red cursor and blue cursor on both ends of the line (or close to them).
- Read the value Slope(um/DU). This value should equal, or be close to within +-10% to the default Slope value sensor was loaded with. The default values are available from Parameter pane field Slope (see [Figure 3-25]). If this value had been already changed, use the one from the table below:

Table 4-2 recommended Slope values

objective	Slope (um/DU)
5x,0.14NA	1.0
10x,0.28NA	0.20
20x	0.05

NOTE:

If ATF6 sensor is accompanying with manufacturing production record it is recommended to match slope with the one recorded during production.

If characteristic you are observing has slope value ***lower then prescribed*** you need to shift sensor toward ***increasing X*** as per [Figure 4-1].

If characteristic you are observing has slope value ***higher then prescribed*** you need to shift sensor toward ***decreasing X*** as per [Figure 4-1].

- ***Adjust sensor shift along Y (see [Figure 4-2]) by observing laser line characteristic on high objective (50x)***
- Change objective to highest available magnification, typically it is 50x. This objective should be chosen because of the smallest entry aperture.
- Bring image to focus.
- Move Z stage up and down +-20 or +-40um in case of 50x and observe the effect of Z motion on defocusing of the ATF6 sensor laser illumination.
- If ATF6 laser line is entering objective aperture at center (with respect to Y direction) then result is going to be degeneration of the thin line into thicker one symmetrically to both sides as z is changed symmetrically around best focus. (see [Figure 4-4])
- If ATF6 laser line is entering objective aperture asymmetrically then it will became evident in laser line not only becoming thicker (up and down on [Figure 4-4]) but more importantly developing skew toward left and right.
- This is try and error process, since angle change is going to be very minute. The recommended way is to move the kinematic screw responsible for

moving laser line left and right (as per figure [Figure 4-4]) and then change Z and verify if shift is still present.

- At the end of the adjusting process it is possible to achieve condition of laser line entering objective lens symmetrically at the expense of line being shifted toward edge of the image. If so, this may or may not be a problem, depending on the next step.
- Image on the left indicate center of the line traversing up and down with the change of the distance. While Image on the right shows skew that developed if ATF6 laser illumination is not centered.

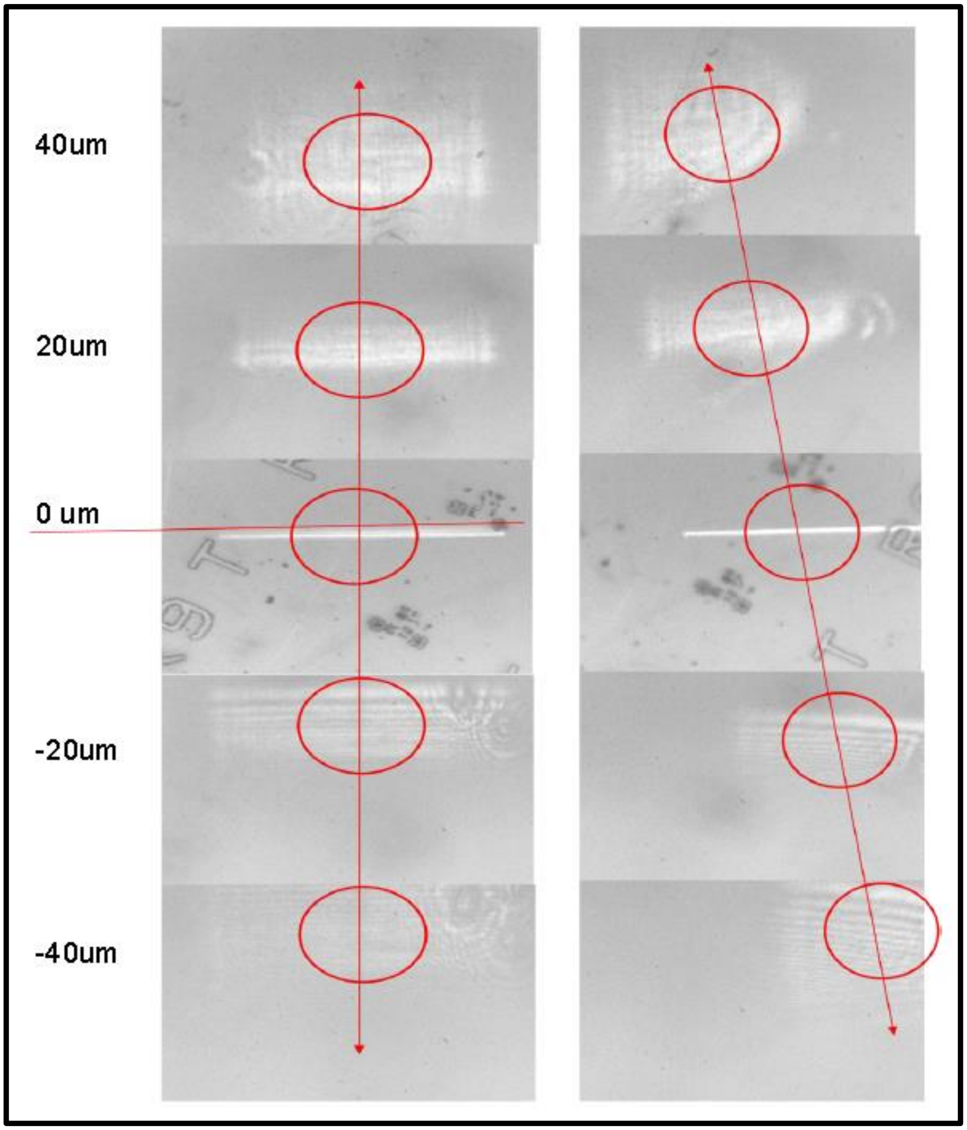

Figure 4-4 Illustrates effect of Y shift from the center of Obj Aperture evident @50X Objectives.

- ***Adjust sensor shift along X (see [Figure 4-2]) on high objective (50x) if capture range is compromised.***
- With high objective in focus execute 'Move&Graph' over the range of 200um, with the step of 2um. You should obtain the characteristics similar to the one depicted on figure [Figure 4-11].

  If characteristics shows less than 200um range, symmetrically on both ends, this may indicate that sensor is mounted with too much shift toward X direction as per picture [Figure 4-1]. In such a case, not enough light is going to reach sensor back because most of the light is missing relatively small aperture for high objective. Shift sensor slightly, about 0.3mm toward decreasing X and rerun Move&Graph. Observe if the capture range is going to be larger. If so you may repeat the process one more time and again verify if capture range reached full range of 200um.

4.2. SENSOR ADJUSTMENT PROCEDURE

Optical elements, external to the sensor, may affect the optical path inside it resulting in a deviation from the optimal alignment. This should be corrected in the field using the procedure detailed below:

- Make sure that the sensor is properly installed according to the procedure from paragraph 4.1.
- Connect the sensor's RS232 cable to the PC and run the ***ATF6_Test*** software (supplied with the sensor).
- Install 5x (or the smallest magnification used) objective lens.
- Select the communication port (main screen drop-down menu) to which the sensor is connected, as shown in [Figure 4-5]. Put the specimen under the microscope.
- Adjust microscope position to bring laser line to focus. Use review camera as a feedback.

○

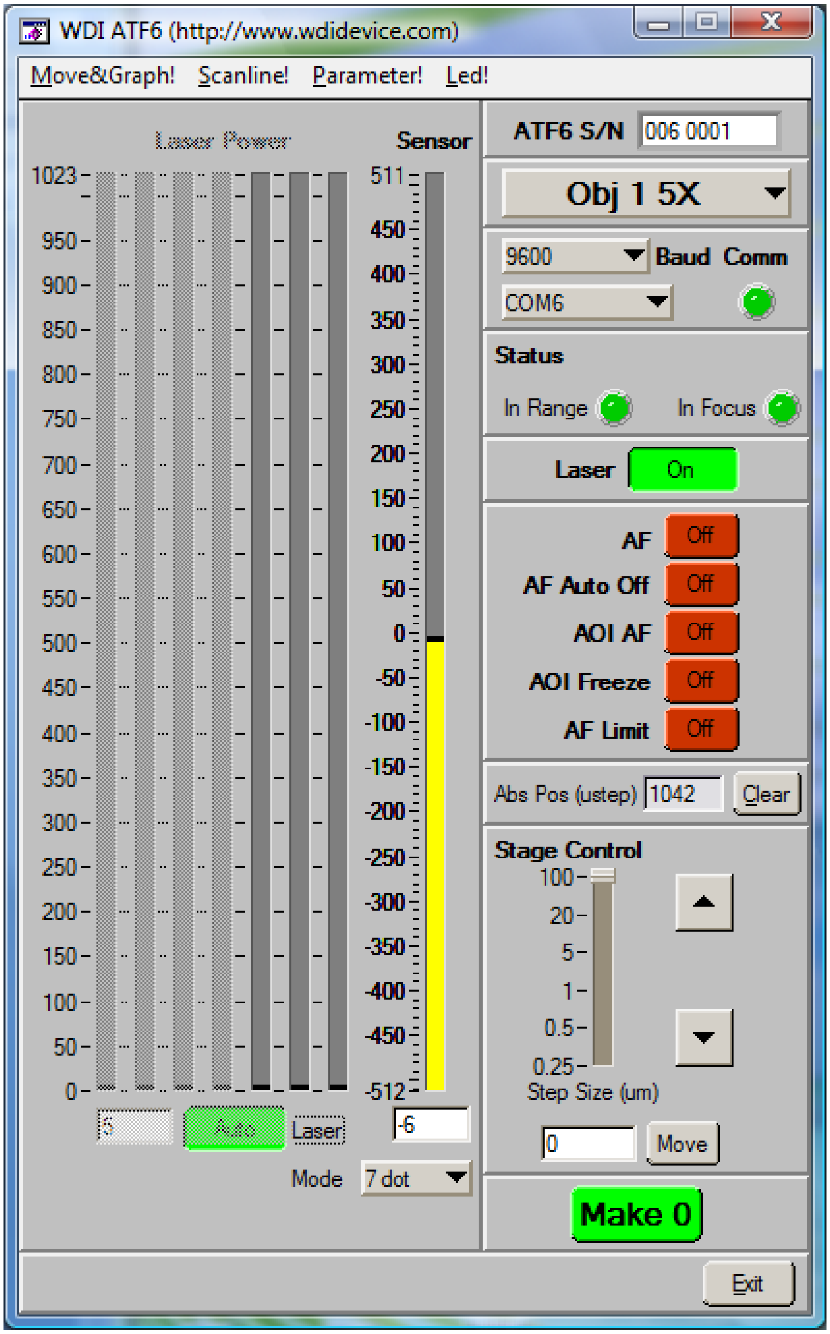

Figure 4-5 ATF_Test Main window

- Increase baud rate to the highest reliably working speed. Reading one scanline may take 10 seconds at 9600 baud rate.
- Select option "Scanline!" from the main menu. In the Window Mode drop down menu select "Far" and select "On" for Center Far Window.

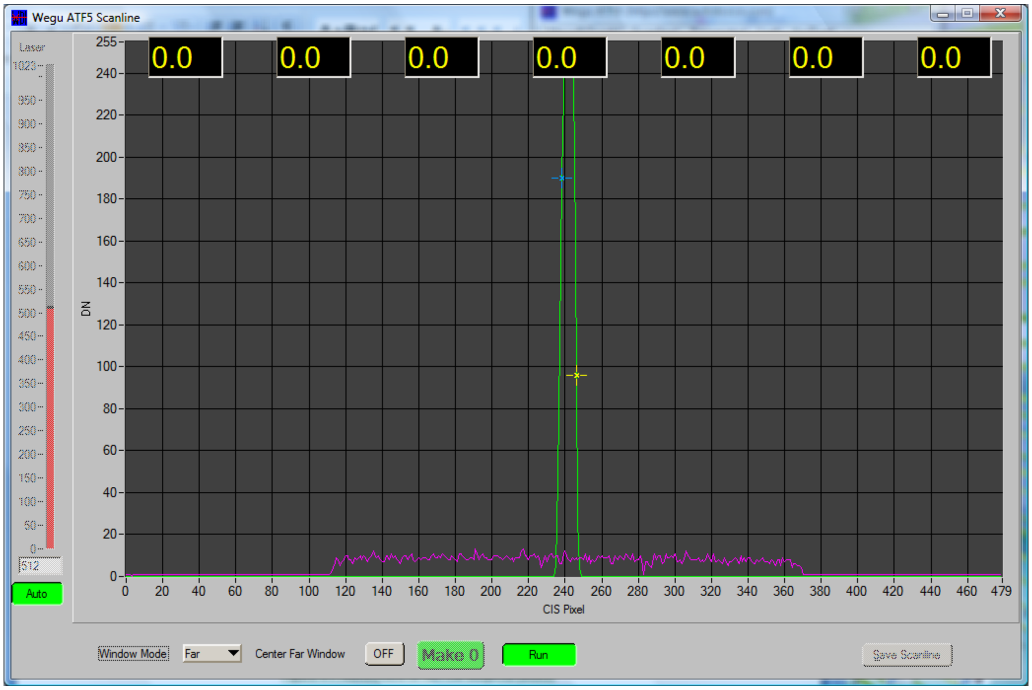

Figure 4-6 Far mode with narrow measuring peak (green) and broad ridge (purple).

- Please note that green peak is at 240, while purple is centered with 240 and extends from 120 to 360.
- Adjust the Green scanline by turning the adjuster screw A (not sealed by red enamel) to position 240, Figure 4-6 and Figure 4-7
- Adjust the Magenta scanline by turning the adjust screw B (not sealed by red enamel) to position 240,
- When finished lock adjuster screw A and B using the set screw.
- Change back to “Auto” mode. Click “Make 0” in the Scanline Window.

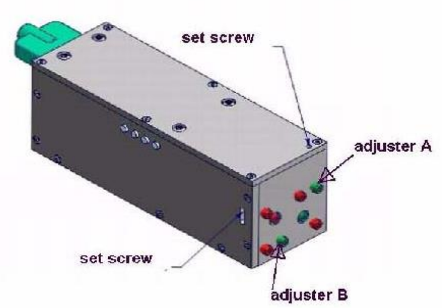

Figure 4-7 Adjustment screws

4.3. SENSOR SETUP

In multiple lens switching application, it is necessary to inform and train the sensor with each objective lens.

1. Open the Parameter window from ***ATF6_Test***.
2. Set objective lens setting by inputting magnification and DUV in accordance to position on lens changer and close window [Figure 4-8].
3. Close the parameter window.
4. Place the lowest magnification lens and focus the image.
5. Select the lens from the drop down menu on the main ***ATF6_Test*** window.
6. Place the whole line in clear area (i.e. ITO or metal pad) and click "Make 0"
7. Place the next higher magnification lens in place and focus image.
8. Repeat step 4-6 until the last lens.
9. Press “Save to sensor” button found in the parameter window

After each time “make 0” is performed, verify the sensor has been successfully trained by:

- Observe that value reported by sensor stays at 0 +-10 units
- Execute ‘Move&Graph’ and measure the slope of the line while in linear mode. Use the measured slope to update the Parameter->Slope field.
- Run the scanline and verify that:
- In Far mode the central green peak is placed at 240. There are no other green peaks visible.
- In Far mode the purple peak extends from about 120 to 360 as per figure Figure 4-6
- In Auto mode all 7 peaks are visible. All of them are about the same height (+-20%) and set at equidistance from each other.
- Move stage Z to be at least in +-300 DU range and observe that laser power in any of positions in between is not LOWER then laser power at best focus (0 position) by more than 30%
- Laser power value at focus should be less than 150 on typical specimens. (e.g. polished silicon 5x: 8, glass 5x: 50)

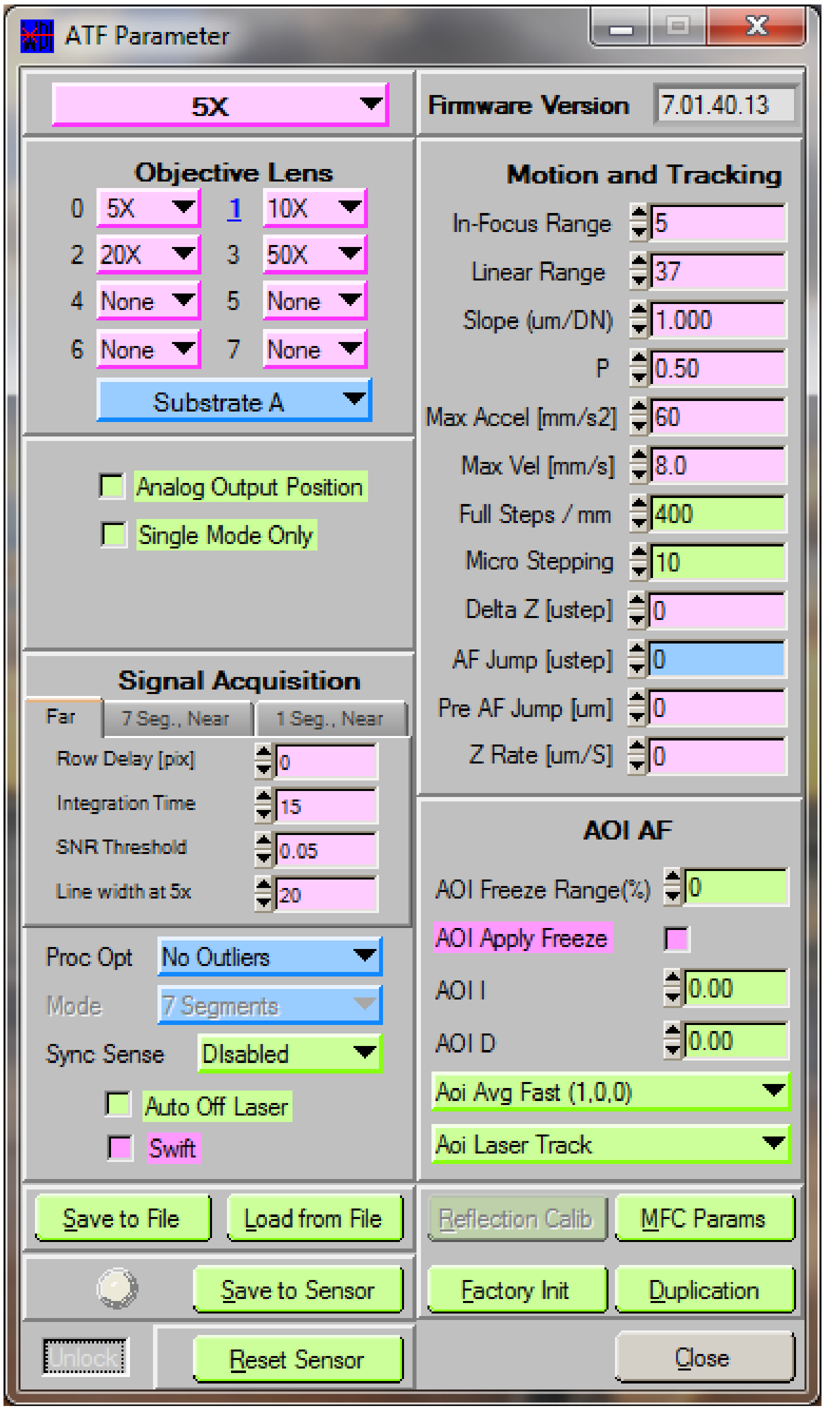

Figure 4-8 ATF6_Test parameter window

Due to the optical property of DUV lens, red light focus is offset from green and blue light. DUV lens setup requires extra steps:

- Switch to DUV lens and select the lens from the drop down menu on the main ***ATF6_Test*** window.
- Open scanline and set Window Mode to "Far".
- Adjust the "Z" axis controls until peak width is at visual minimum.
- Set Window Mode to "Auto" and click "Make 0".
- Adjust "Z" axis controls until minimum number appears in the Area Boxes.
- Click "Make 0" (sets at focus on red plane).
- Record the Absolute Position number found on the parameter window.
- Adjust "Z" axis controls until image is in focus.
- Record the Absolute Position number. Find the difference between the current and previous Absolute Position number, this gives the Off Set.
- Open the Parameter window and enter the Off Set beside the selected DUV lens.
- Set motion parameters.
- Test AF auto focusing ("Z" axis will move to the sensor focus, red plane, and then the "Z" axis will move using the Off Set number to the image focus position, blue and green plane).
- If more than 1 DUV lens is used repeat steps 1 to 13 for all DUV lenses.

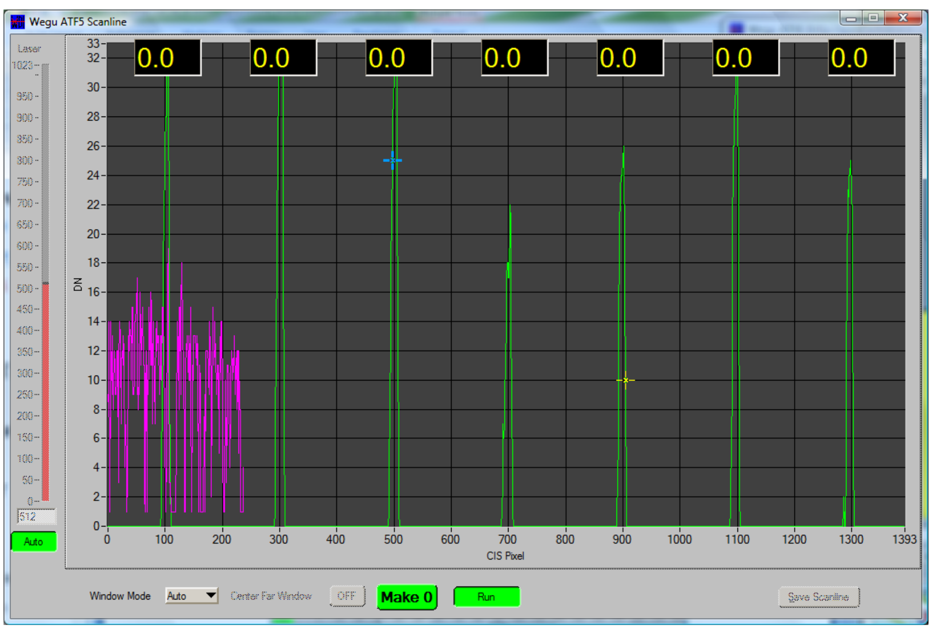

Figure 4-9 Scanline after "Make 0"

4.4. FINAL SENSOR ALIGNMENT VERIFICATION

For final sensor alignment verification it is recommended to run the capture range test. Users, who have purchased the sensor together with the Motor Controller option (not SA, analog output), can use the "Move & Graph!" tool. Users, who use their own motion control system, are advised to follow the guidelines below to estimate the sensor capture range.

- With ***ATF6_Test*** software running, the Motor Controller users should select the communication port (main screen drop down menu) to which the Motor Controller is connected, as shown in the figure below.

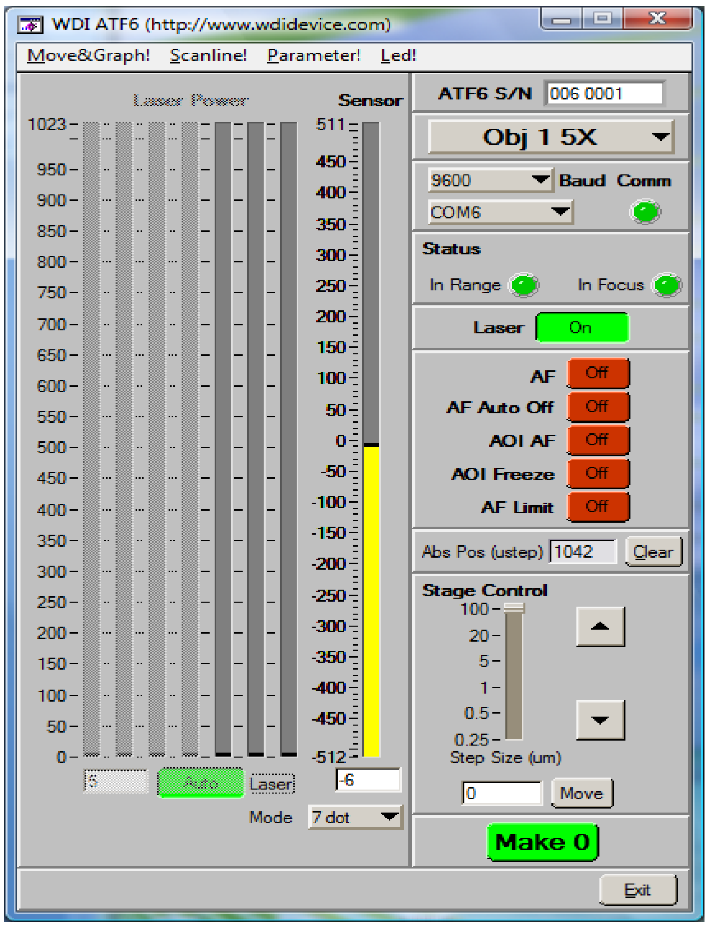

Figure 4-10 ATF_Test Main panel

- Open "Move & Graph!" tool from the main menu. Fill in the input fields

"Start (µm)", "Step (µm)", and "End (µm)" with desired values.

- Make sure the output is near 0. Click button "Go" and observe the sensor characteristic.

- For properly aligned sensor the capture range plot should look like it is shown in the Figure 4-11. (Objective lens x100 and LCD TFT array were used in this case. The laser dot was targeted onto the LCD cell area, covered by indium-tin oxide (ITO) film).

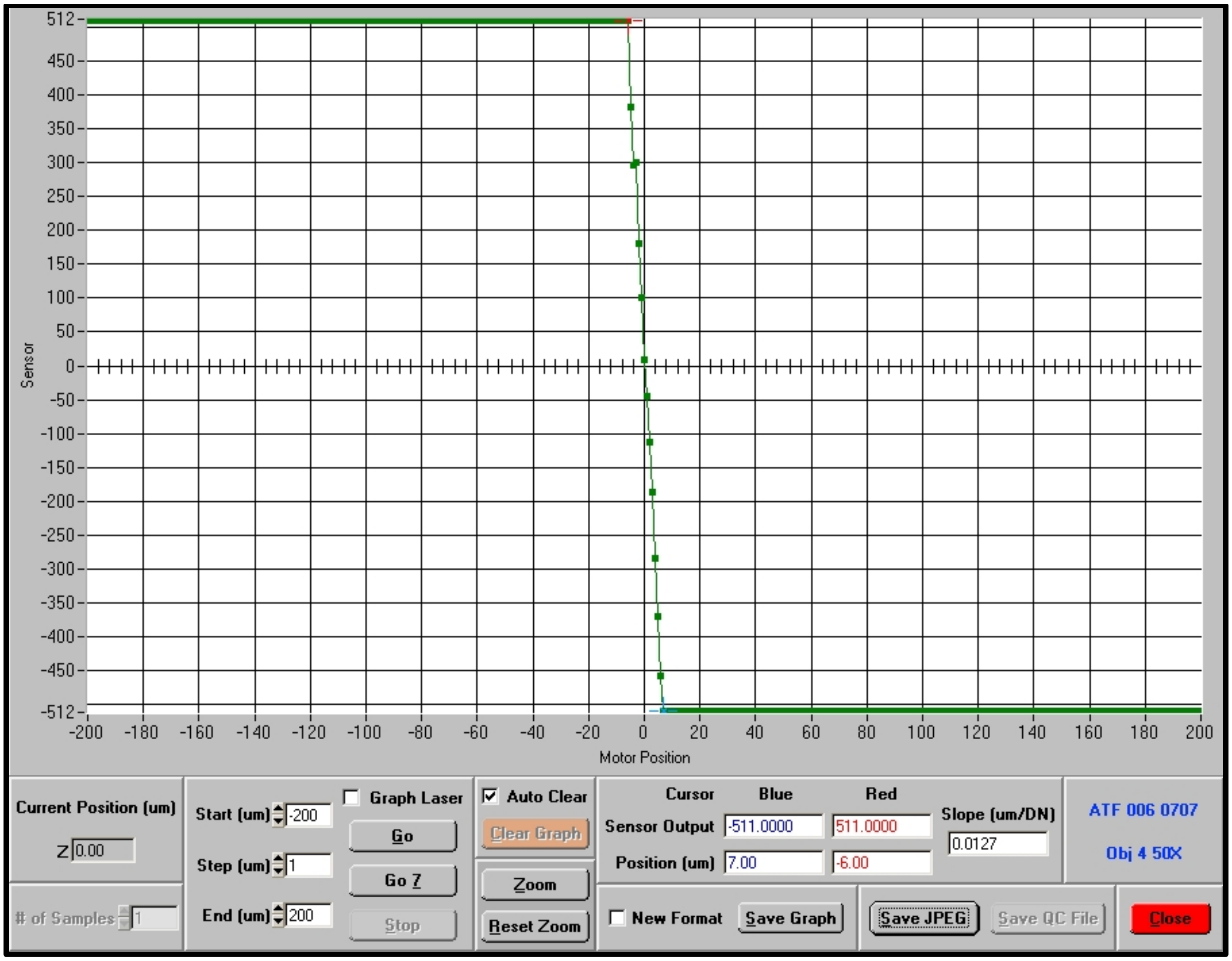

Figure 4-11 Capture range for properly aligned sensor (objective x50 – LCD specimen)

- The 200; 200] microns capture range was observed in this case. The "linear range" detailed plot is shown in figure below. The deviations from linearity, similar to shown below are observed in case the specimen consists of areas with different reflectivity.

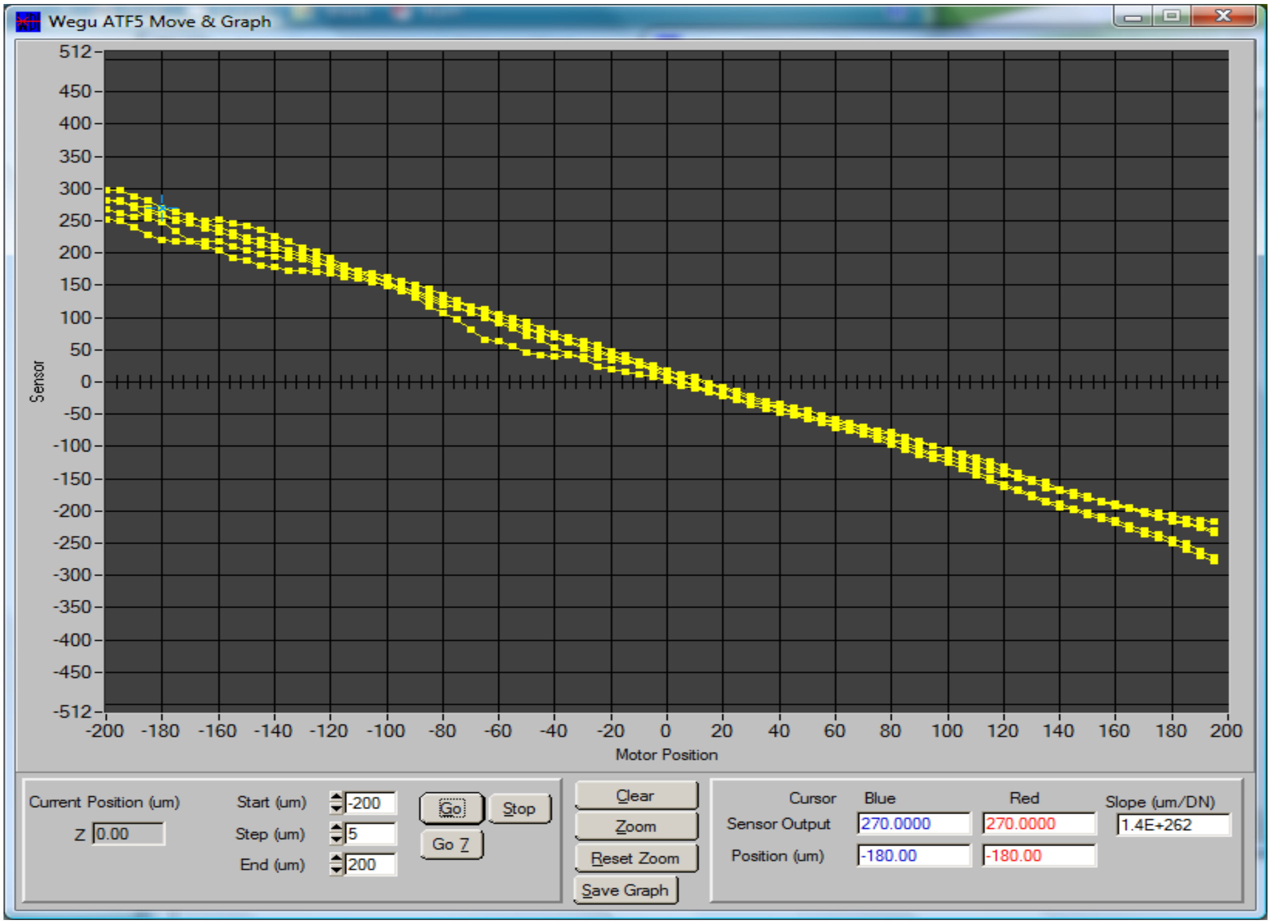

Figure 4-12 Linear Range detailed plot for properly aligned sensor w/ 5X Objective on Si Wafer.

Chapter 5

SPECIAL APPLICATIONS

5.1. SWIFT TRACKING

The ATF6 comes with WDI's powerful SWIFT tracking system. This system combines the ATF's fast focus abilities with a specially designed dynamic PID controller algorithm. It can be used to improve the ATF6's ability to track moving targets.

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5.1.1 SWIFT Tracking

Before activating SWIFT, bring the sample into focus using the UP and DOWN buttons in the Main Console Window (as shown in Figure 5-1).

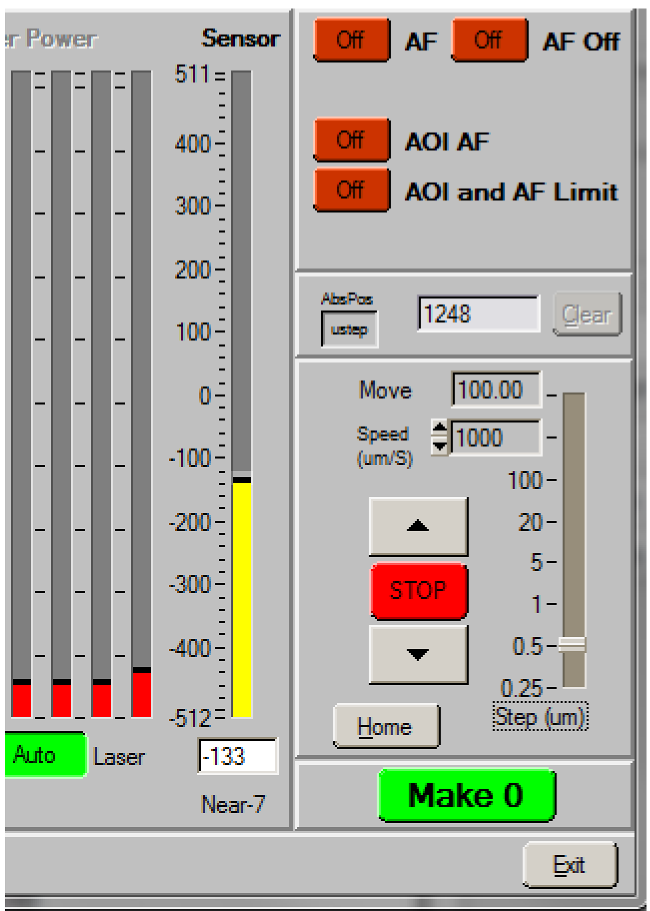


Figure 5-1 The Main Console Window

To activate the SWIFT Tracking System, first select *Parameter* from the *Configuration* menu. This will open the *Parameter Window (Figure 5-2)*. In the *Parameter* Window, click the checkbox labelled *Swift* (as shown in *Figure 5-2*). If this option is not available, unlock the console by typing ATF6 into the *Unlock* control, located in the bottom-left of the *Parameter* Window.

When the *Swift* checkbox is selected, a pop-up window will appear (*Figure 5-3)* which warns that any change in the CM parameters requires the Make0 routine to be run before the change takes effect. Close the Parameter window and bring the sample into focus. Once the sample is in focus, click the *Make0* button in the main console window. The SWIFT Tracking System will now be activated.

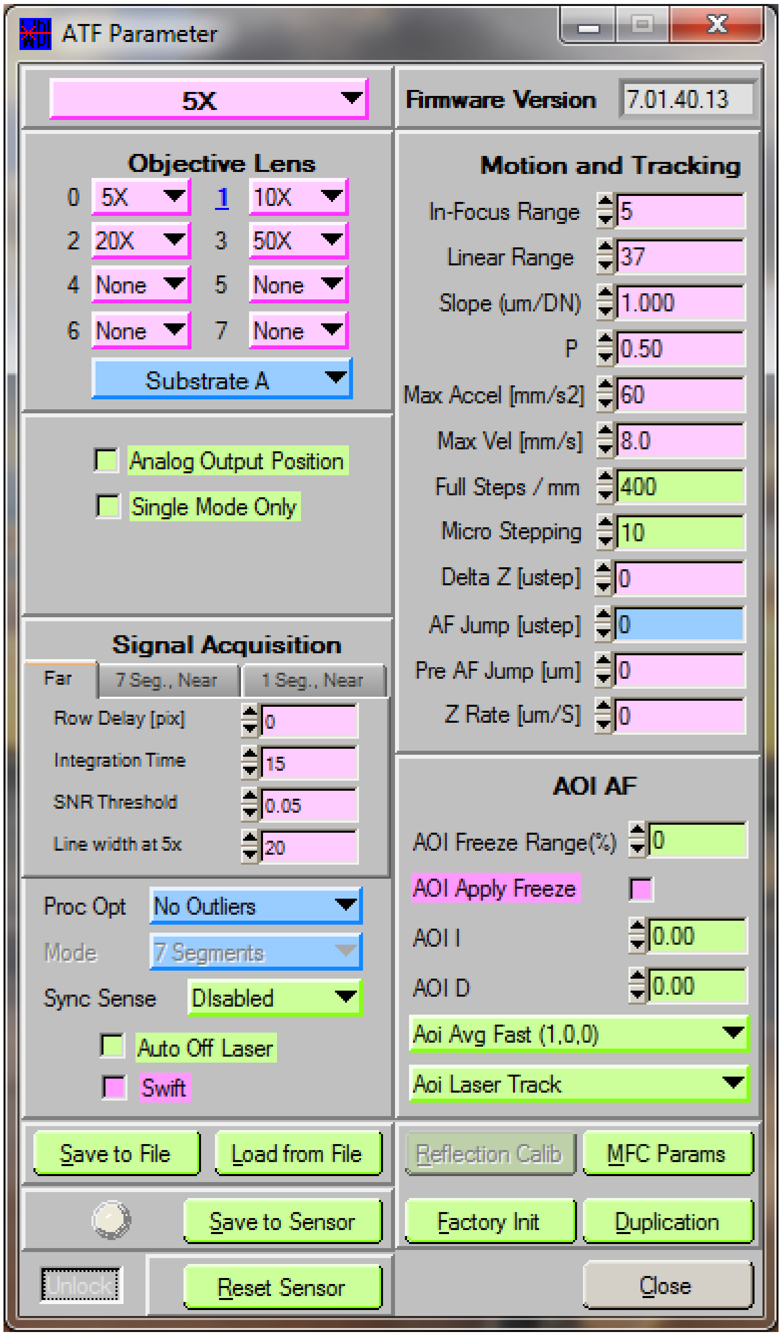


Figure 5-3 The Parameter Window

Before utilizing the Swift Tracking system, it must be properly calibrated. This is achieved in two steps. First, the sensor's slope must be determined. To do this, select *Move&Graph* in the main console window to open the *Move&Graph* Window (*Figure 5-3.)*

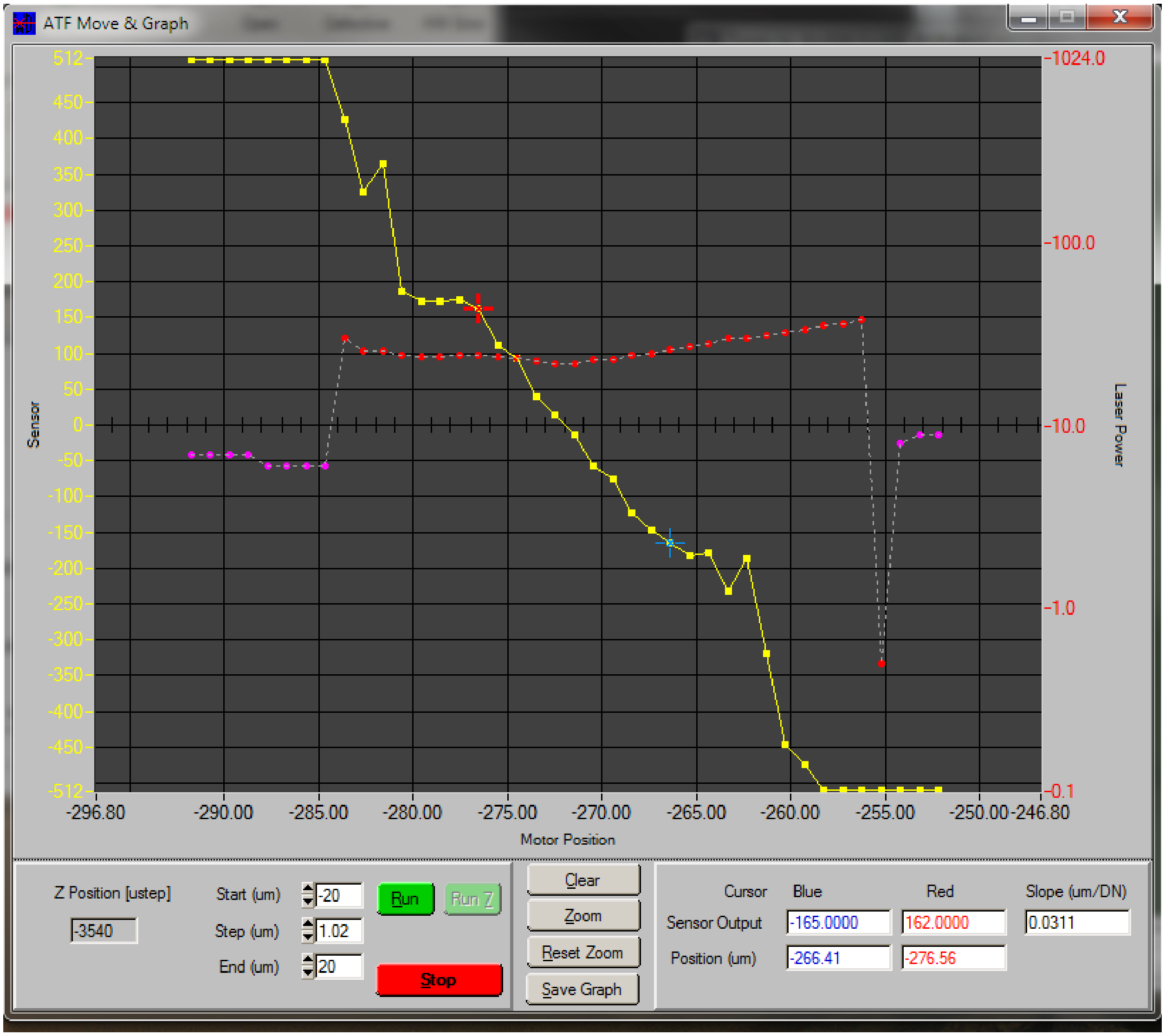


Figure 5-3 The Move&Graph Window

In the Move & Graph Window, enter Start, End and Step values appropriate for the currently selected objective lens. For a 5x objective lens, WDI recommends a Start value of -200um and an End value of 200um with a step size of 10um. For a 50x objective lens, the End/Start values should be ±20um with a step size of 1um.

Before clicking Run ensure that the actuator has a sufficiently large range of motion to move through the selected range. Click Run to begin the Move & Graph process. Once the process is complete use the red and blue cursors to find the slope of the yellow line as it crosses the X-axis at 0. If the yellow line does not appear, does not cross the X-axis, or crosses the X-axis more than once, the sensor is not properly calibrated. See Chapter 4 for Sensor Calibration instruction.

Once the Slope has been determined, note it down and close the Move&Graph window. Re-open the Parameters window and enter the Slope value obtained from the Move & Graph process into the Slope parameter.

The second part of the Swift calibration procedure involves tuning the AOI parameters. To do this, open the AOI Parameter Tune-up window by clicking AOI Test in the Configuration menu. In the AOI Parameter tune-up window, ensure the Capture Size is set to 512. Clear the window by pressing the Clear button, then switch the Step process ON. The graph produced will contain a green line, a magenta line, a red line and a blue line. The Green and Magenta lines should both be symmetric about the X-axis. If they are not, adjust the P Asymmetry parameter to make them as symmetrical as possible. Once this is complete, the ATF AOI Parameter Tuneup window can be closed and the SWIFT Tracking system is ready to use.

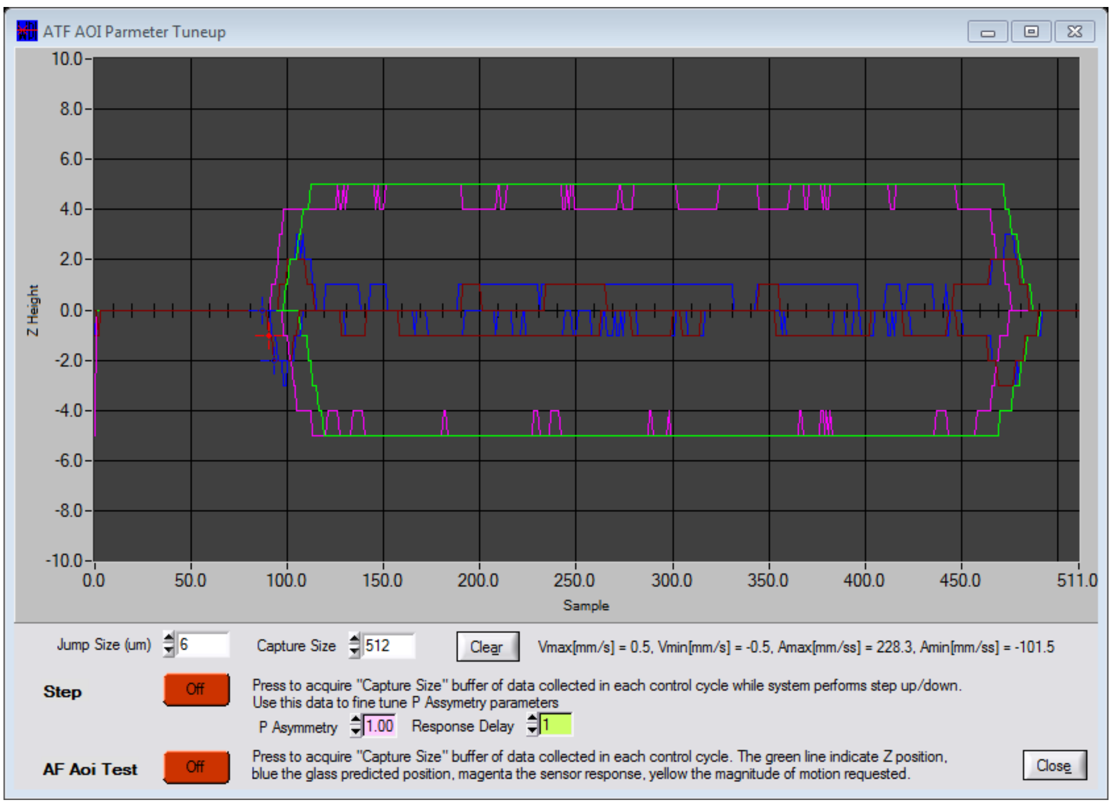


Figure 5-4 AOI Parameter Tuneup Window

5.1.2 AOI SWIFT Auto-Parameter Tool

The WDI AOI SWIFT system uses a PID control algorithm to implement auto tracking control. In order to optimize the PID algorithm, a new tool, the AOI SWITF PID auto-parameter tool, has been designed to automatically find a good set of PID parameters for the currently installed sensor. Before using the tool ensure that the sensor is properly aligned, as outlined in Chapter 4, and that the SWIFT system has already been set up (see section 5.1.1).

The tool will be installed simultaneously with the ATF Console Software. After installation, the tool can be accessed from the WDIDevice submenu in the programs menu. To run, simply click the shortcut.

Before running the tool, ensure that the Max Acceleration & Max Velocity values set in the Parameters window does not exceed the maximums allowed by the currently installed stage actuator. Test the movement of the actuator with the default settings. If no slipping occurs, continue. If slipping occurs, reduce the values.

It is also recommended that the In-Focus Range is set to either 0 or a minimal value to improve motion target tracking. If the sensor suffers from instabilities, increasing the In-Focus Range can stabilize the sensor.

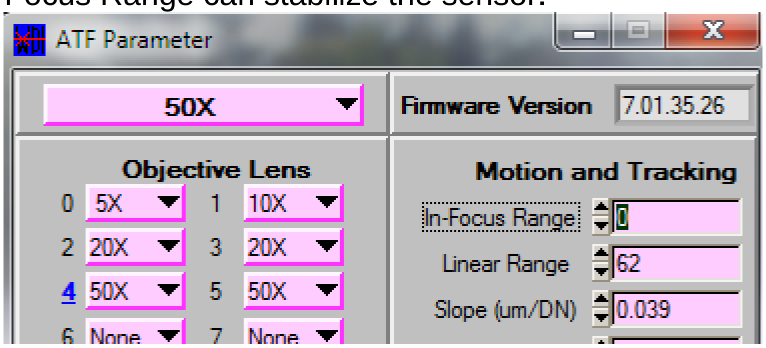


Figure 5-6 In Focus Range setting

Upon startup, the AOI PID Parameter Tool window should appear. If it does not, reinstall the tool. The AOI PID Parameter Tool window is shown in Figure 5-7, below.

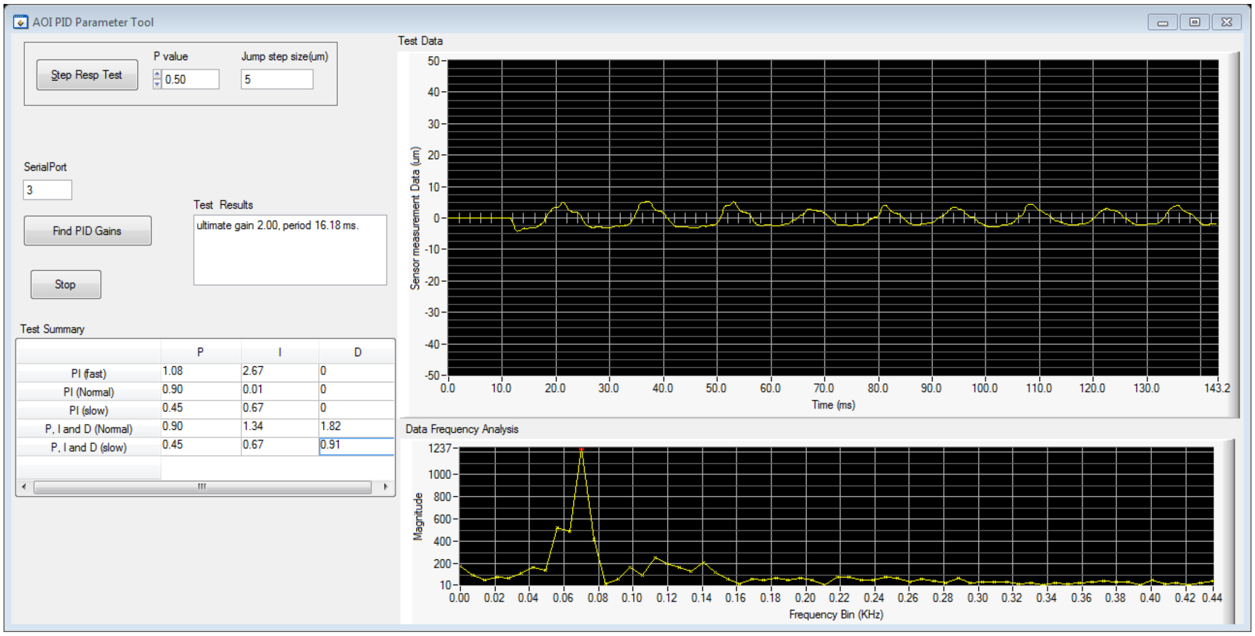


Figure 5-7 The AOI PID Parameter Tool

Before starting the auto tuning process, ensure that the correct serial port is entered into the SerialPort numeric control, and disconnect other WDI tools (ATF Console, Wloader, etc.) from the sensor.

The Step Resp Test tool can be used to test the response of the system. To use this tool select an appropriate P-value and step size, then click the Step Resp Test button. The system should then move the stage in the z-direction a distance specified by the step size. It will then return to the in-focus position. Monitor the Test Data graph to ensure the sensor responds appropriately to this motion. If it does not, or the motion does not complete correctly, re-align the sensor by following the methods outlined in Chapter 4.

Before returning to the AOI PID Parameter tool, ensure that the Make0 routine has been run to establish the microscope's in-focus point.

To begin the auto tuning process, click the Find PID Gains button. This will begin the auto-tuning process. The recommended settings will be shown at the Test Summary table once the process is complete. These settings can then be entered into the Parameters window of the ATF Console.

In most cases, a PI control is the best choice for motion target tracking. In these cases, the P and I values should be entered into the Parameters window, with the D value set to 0. After running the AOID PID Parameter tool, incremental adjustment of the recommended values may be required to optimize the parameters for a particular application. Increasing the P and I values may improve tracking but reduce stability.

Reducing the P and I values may improve stability. The tool is based on Ziegler-Nichols frequency (closed-loop) method.

Once the autotuned parameters have been inputted into the system, the SWIFT system can be calibrated and run from the ATF Console.

5.2. VIDEO AUTOFOCUS

The ATF6 is also equipped with Video Autofocus (Video AF). This allows the ATF6 to take advantage of image sensitive video techniques and precisely detect the best focal plane on patterned targets, where laser AF may fail. Combining laser and video autofocus allows the ATF6 to work on virtually any surface.

In order to properly initialize Video Autofocus, the LED illumination should be adjusted to optimal settings. This can either be adjusted manually using the **LED Window** or by using the **Auto Gain Search button** in the **Video Focus Panel**. The optimal focussing algorithm must also be selected. This can be achieved in the Video Focus Panel.

5.2.1 Video Focus Panel

To open the Video Focus Panel open the *Configuration* menu and select the Video option (see **Figure 5-8)**

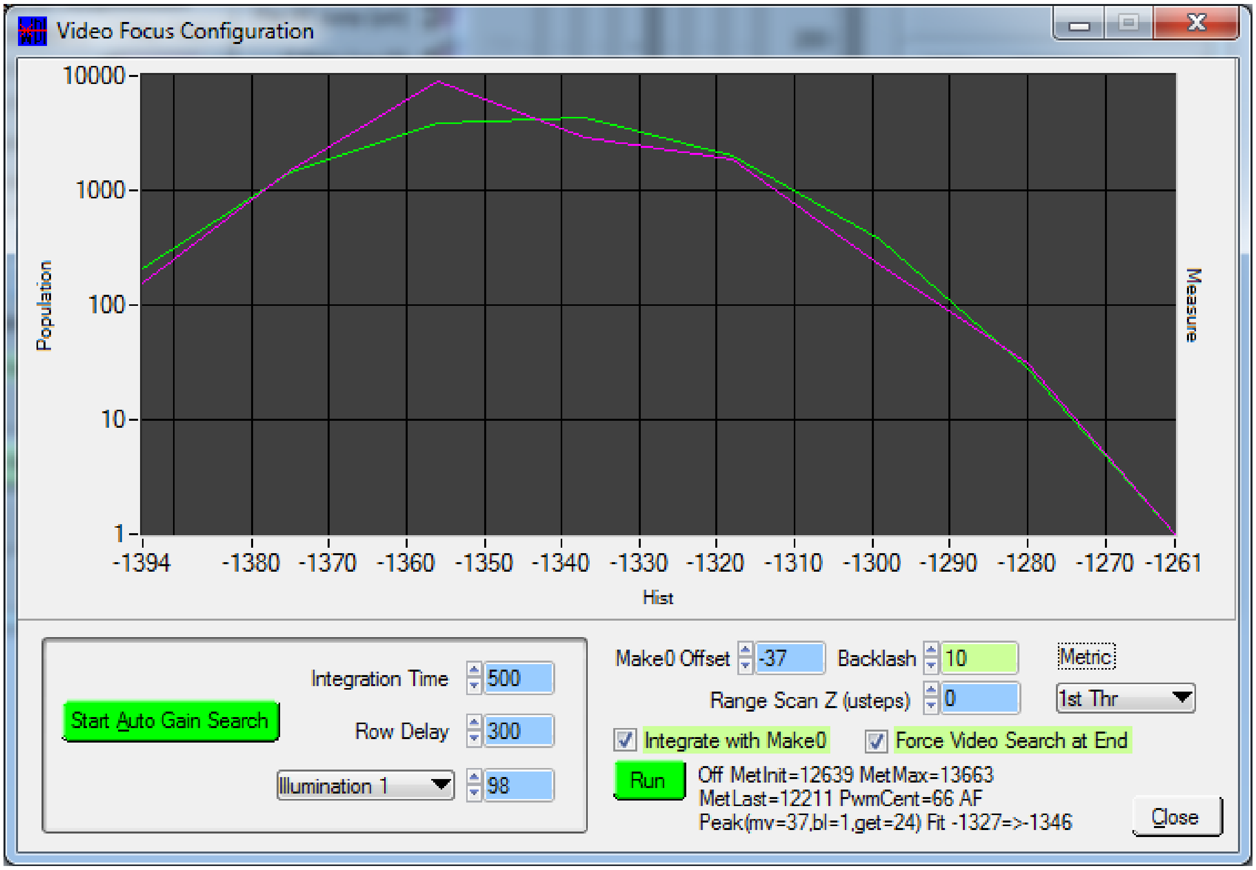


Figure 5-8 Video Focus Panel

The Video Focus Panel contains 3 main sections: The graph module, the illumination module, and the Video Focus controls.

The Graph Module

This section displays graphical information about the video autofocus status. It operates in two modes: Illumination Mode and Best Fit Mode.

Illumination Mode displays the light distribution on the X axis and the number of pixels on the Y axis. This mode is activated when Auto Gain Search is selected, and shows the user the illumination status of the system.

Best Fit Mode displays the best focus metric (magenta) and best focus metric prediction (green) versus absolute position. This mode is activated when video autofocus runs. In order to achieve best focus, the metric and prediction should match as closely as possible.

The Illumination Module

The illumination module contains 4 controls.

- The **Start Auto Gain Search** button activates the automatic procedure for finding the optimal illumination settings for video autofocus. When this button is pressed, the system will search for and apply the optimal illumination settings. The other displays in the Illumination Module will change accordingly.
- The **Integration Time** numeric control displays the exposure time in microseconds. In addition to being a display, it is also a control, allowing the user to type in the desired exposure time.
- The **Row Delay** numeric control displays and controls the amount of additional time to be added to the exposure in time units corresponding to one pixel readout. This control accepts values of 0 to 140, in increments of 100.
- The **Illumination** numeric control controls and displays the Illumination PWM value. The illumination can be selected from 3 different sources: LED1, LED2 or None.

The Video Focus Controls

The video focus controls consist of 3 numeric controls, 2 check boxes, and the **Run** button.

- The **Make0 Offset** numeric control displays and controls the distance in microsteps between the best focus plane measured by the laser and the best focus plane measured by the video focus metric. This parameter is automatically calculated by the Make0 procedure.
- The **Backlash** numeric control displays and controls the distance moved in microsteps before any visible effect occurs. This parameter should be estimated to ensure that the system ensures that best focus is always approached from a distance larger than the Backlash parameter, allowing a higher accuracy of focus estimation. This parameter will *not* be automatically set, and must be estimated manually.
- The **Range Scan Z** numeric control displays and controls the distance in microsteps moved by the system during the video autofocus search. This is set to 0 by default, allowing the system to internally calculate the necessary distance. The Range Scan Z parameter should not be set unless the Laser AF fails to reach focus.
- The **Integrate With Make0** checkbox allows the user to integrate the Auto Gain Search with the **Make0** command in the main window. This allows for

the automation of the Video AF initialization.

- The **Force Video Search At End** checkbox allows the user to force the system to execute a metric search each time the Video AF button is pressed. If it is not set, Video AF will only activate if the system determines that Laser AF has failed.
- The **Run** button disables the laser AF and switches entirely to Metric calculation mode. While this mode is active, the currently calculated metric value and the illumination average will be displayed to the right of this button. Clicking **Stop** will disable this mode.
- The **Metric Menu** allows the user to select the Focus Algorithm to use. Before choosing your algorithm, please go through the next section **Setting Up Video AF** to find the optimum algorithm for your sample.

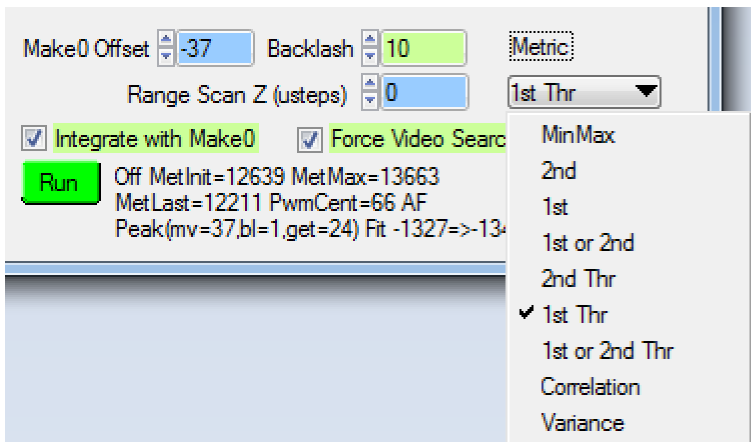


Figure 5-9 Metric Menu

5.2.2 Setting Up Video AF

To set up Video Autofocus, please complete the following steps:

1- Prepare your sample, and bring it into focus using the Z-motion controls on the left hand side of the main control panel. Try to find a relatively smooth area of the substrate, to allow the Laser Autofoucs to perform adequately.

2- Open the Video Focus Panel and *deselect* the **Integrate With Make0** checkbox. Then press the **Make0** button.

3- Open the Move & Graph window, select a range around the focus plane (typically ±200 micrometers) and press the **Run Video** button.

4- Observe the shape of the plotted graph. If the graph does not have a single clear peak, or has a very noisy signal, open the Video Focus Panel and select a different focussing algorithm. If the tip of the peak is noisy, the system requires more illumination. If the graph rises on either side of the peak instead of dropping, the system requires less illumination.

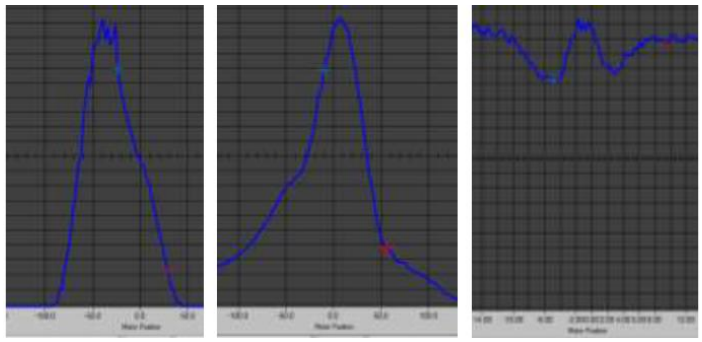


Figure 5-10 Examples of graphs with (a) Noisy Peak, (b) Ideal Peak, (c) Over/Under Illumination or ineffective metric.

5- Once a clear peak has been found, open the Video Focus Panel and select the **Integrate with Make0** checkbox. Then perform the **Make0** routine again.

6- The graph module in the Video Focus Panel should now display the Metric curve and the predicted metric curve. Ensure that the system has accurately predicted the metric. If it has not, try increasing the backlash or attempt a different focussing algorithm. If the Metric and predicted metric agree closely (see figure 5-10 for an example of this), the video Autofocus is ready to use.

5.3. CELL AND MODULE (CM)

ATF6-Cell Module Autonomous autofocus system for LCD cell inspection/repair. The focus is on the user-selected surface of the multi-layer transparent structure. CM sensor stands for "Cell and Module sensor." WDI models ATF 6CM are well suited for focusing on multiple transparent layers, such as TFT cells.

5.4. AUTOMATED OPTICAL INSPECTION MODE

5.4.1 GENERAL DESCRIPTION

The Automated Optical Inspection (AOI) Mode is designed to be used with the scanning applications of ATF6. In such applications the microscope must maintain focus - track focus - during the microscope motion.

The examples of such applications are:

- AOI scanning systems utilizing line scan cameras
- AOI systems utilizing area scan cameras with strobe illumination for optically freezing the image in spite of camera motion during its exposure time

The AOI Mode is designed for 5, 10, and 20x objectives and it will not operate with 50x and 100x objectives because of the restrictive (narrow) capture range.

NOTE:
The maximum scanning speed is strongly influenced by the specimen flatness (rate of height change) and thus cannot be reliably specified. Please contact ***WDI*** for the application support.

The following are the software facilities specific to the AOI Mode:

- The dead band of half of the depth of field is deactivated. This facilitates quick response to changes in specimen's Z position.
- The Proportional-Integrating (PI) method of servo-control is used (in Stop-&-Focus mode just proportional controller is sufficient)
- Only 7 line segment mode is used with update rate higher than 1kHz
- The digital filter is applied to the sensor output to eliminate erroneous readings on transitions taking advantage of previous sample history.

5.4.2 SOFTWARE INTEGRATION

The following is the order of commands to activate and deactivate the AOI Mode:

Table 5-1 AOI Mode commands

Command	Action
U8	Go to focus and turn auto-focus off when focused
U9	Start AOI tracking auto-focus, At this point stage can advance along the glass.
U7	Stop auto-focus

5.5. AOI TRACKING ON ATF6-PZ

5.5.1 GENERAL DESCRIPTION

This section describes steps that are necessary to set up AOI AF tracking functionality of the ATF PZ sensor. The described procedure assumes that ATF sensor is mounted and aligned on the microscope system equipped with motorized Z stage under the control of ATF sensor.

Currently ATF SYS sensor supports stepper motor stages through MCM+/MCZ/MFC WDI step-and-direction controllers or ATF PZ AO analog output sensor supports piezo stage if high voltage linear amplifier is supplied by third party. In both cases ATF sensor is acting as a close loop servo controller and requires optimized parameters provided in order to dynamically track target with continuously changing Z position within required error.

ATF sensor supports 2 basics mode of operation AF tracking and AOI tracking.
In AF tracking mode ATF sensor is issuing move commands based on most recent measurement. The next motion is initiated only when motion before has completed. Each motion has a trapezoidal (or triangular) shape. This mode is recommended for reaching focus in case of stationary target.

In AOI tracking mode ATF sensor at a fixed interval of about 2 ms is measuring distance to focus which is used as a close loop error fed through modified PID controller implemented in ATF firmware resulting in speed correction. This mode is recommended for continuously moving targets.

Adjusting AF tracking mode is simpler because it doesn't require full knowledge of the stage dynamics. Only the stage performance max speed/acceleration needs to be accounted for. AOI tracking has to account for stage time domain response.

This document assumes reader being already familiar with:

- "ATF6 Auto Focus and proximity Sensor User Manual", ver. 1.9 [1]
- "ATF4,5,6 Sensors User Guide", ver. 1.3 [2]
- "ATF5,ATF6 Console Software Reference manual", ver. 1.1 [3]

Instead of repeating subjects already discussed in those texts whenever possible references are going to be used.

ATF PZ AO sensor feature is supported in following software:

- ATF_Console ver. 3.2.45
- ATF PZ AO Firmware 7.1.24.16

ATF PZ AO sensor is controlling stage through analog output (AO). The range of analog output available is ±8V. This range is mapped to approximately +- 1495

(exact value may change) values of ADC converters. ATF_Console once connected to the ATF sensor is presenting current ADC value as AbsPos on a main panel. Please note that this value will never exceed prescribed ADC range.
Further sections assume the following hardware/software configuration:

- ATF6 AO PZ system is mounted and aligned on the microscope
- ATF6 AO PZ analog output drives the amplifier
- Piezo stage is connected to the amplifier
- Amplifier has been fine-tuned and optimized for the piezo stage. It is recommended to test AF tracking system in an open loop mode first. This speeds amplifier + stage response and generally gives better tracking. The nonlinear piezo stack response is linearized by ATF6 feedback without the need to relay on build in SG/LVDS.
- ATF_Console 3.2.45 (or higher) software is connected to the ATF6 PZ sensor running firmware 7.1.24.16 (or higher).
- There is an independent means of establishing Z stage height such as caliper or micrometric screw.
- Microscope objective is in place and target is at best camera focus at AbsPos = 0. This means that system is at focus while AO is set at 0V allowing for maximum motion span.
- ATF6 sensor is producing thinnest line while camera is in focus and amount of back/front light illumination is sufficiently low not to interfere with sensor measurements.
- ATF_Console has selected an objective with a matching magnification to the microscope objective and make0 was performed resulting in a scanlines as presented in the appendix A.

Differences in ATF_Console 3.2.45 supporting ATF6-PZ AO with respect to version 3.2.44:

- Micro Stepping and Full Step/mm parameters are used to map AO DAC change rather than microstep change corresponding to Z distance
- <u>Main->AbsPos</u> is providing analog output DAC value rather than micro step position. The <u>Main->Clear</u> button is not affecting AbsPos

Differences in ATF-PZ firmware 7.1.24.16 with respect to the previous firmware

- Move command calculates change of AO value corresponding to the Z position change and adjusts DAC accordingly. Next move command can be scheduled after the time elapse corresponding to the trapezoidal motion calculated according to Max Accel/Vel parameters

- Speed Move command changes AO value that corresponds to Z position change that has to conform to Max Accel/Vel profile.
- AbsPos reflects AO DAC rather than cumulative total of microsteps done so far

1) Align sensor

Aligning ATF sensor on the microscope is discussed in:

- [1] – Chapter 4 – “Sensor Alignment”
- [2] – Chapter 15 “ATF5,6 Sensor alignment”

ATF-PZ implementation in general agrees with the above descriptions. There are few minor notes:

a) The scanline is centered at 120 out of 240 total pixels, not 240 out of 480 as mentioned in [1] (fig 4-6) . The narrower scanline is necessary since AO sensors are not performing far/near mode switching.
b) ATF AO sensor always operates in far mode, and therefore there is no need (nor possibility) to switch between near/far modes as discussed in [1] chapter 9. Single operating mode makes alignment inherently simpler.

2) Adjust Full Step/mm and Micro Stepping

ATF-PZ requires information to map Z motion distance into AO counts. For back compatibility with stepper motor stages same 2 parameters are used:

a) Configuration->ATF Parameter->Micro Stepping
   Always 1.
b) Configuration->ATF Parameter->Full Step/mm
   Requires calculation of Z span of motion in response to change on the analog output. The ATF_Console lists analog output value DAC value as AbsPos indicator on a main panel.

   In order to arrive at a correct value please use formula:
   Full Step/mm = AbsPos [Dac] / Distance[mm]

where:

AbsPos = DAC delta AbsPos needed to caused Distance motion
Distance = distance traveled in mm

Please use following method to calculate:

- Use up arrow on the main panel move section with a step of 100um to move Z piezo stage to the upper maximum ATF6-PZ could achieve. After few motions AbsPos will reach upper maximum. As an example let's assume it is Max=1495
- Measure Z height with a caliper or equivalent method
- Move to the stage minimum with down arrow. Let's assume that Min=-1495
- Re-measure Z height and calculate delta motion, Let's assume Zd=0.2 mm
- Full Step/mm =(1495+1495)/0.2 = 14950

3) Adjust Max Accel and Max Vel

ATF PZ is using Max Accel/Vel to estimate time required to accomplish motion and to set limits on available speed and acceleration correction issued with every update interrupt

a) Configuration->ATF Parameter->Max Vel
b) Configuration->ATF Parameter->Max Accel

Values of those parameters should be established based on amplifier slew rate and piezo stage specification. The best strategy is to set values that are known to be within capability of the amplifier and piezo stage and once tracking could be proven to work gradually increase them till system performance starts to suffer.

4) Adjust Slope (um/DN)

Slope determines the proportionality coefficient between sensor measurement and motion distance. As such is a critical parameter and needs to be measured accurately. Please follow:

- [2] – section 13 "Move and Graph"
- [1] – section 4.4 "Final sensor alignment verification"
- [3] – section 3 "Move&Graph"

At the end procedure needs to establish Configuration->ATF Parameter-> Slope (um/DN) that is closely matching performance of the system under test.

5) Adjust P sign

P parameter determines static gain in closed loop system If P = 1 then amount of motion scheduled in the next correction cycle equals distance measured to the target in the current cycle. P can be positive or negative depending on the mechanical and electrical arrangement. By default P is set to 1 in AO system. To verify if P is positive or negative test if tracking AF correction bring system to focus or runs away from it.
Do the following:

- Click on Main->Make 0
- Move 50um away from target
- Click on Main->AF and
- Click same button again 1 sec later to disable AF

If ATF6 arrived back at focus P polarity is correct. If system ran away P needs to be flipped and test repeated.

6) Verify AF tracking

At that point basic tracking AF should be working properly. Please test AF tracking by moving away from focus at different distances and initiating AF to observe the system performance. Use on Main->AF OFF AF tracking with automatic off feature to measure length of time AF needed to reach focus. Time is displayed for few seconds on the bottom of the main panel after each completed operation. Please execute the following tests to ascertain system performance:

a) Verify Linear Range and capture range

Move&Graph procedure as described in 4) displays the linear range (when ATF response is linear) and capture range (when ATF response is fixed but sign is preserved). To verify that sensor works at the full capture range as depicted by M&G please execute move close to the edge of capture range in both directions and press on Main->AF to verify that system arrives in focus.

b) Set Configuration->ATF Parameter-> In-Focus Range

In-Focus range sets a limits on sensor position within which no motion is scheduled. This feature prevents continuous hunting around focus that is wearing mechanical components. It should be set as smallest value that prevents continuous stage motions. Typical method to estimate its value is to run Main->AF and bring system to focus. Wait for stage motion to subside and system stabilized at best focus. Then induce short vibration (knock at the microscope frame) and see if stage oscillation stabilizes. If yes, decrease value; if no increase by 1 count.
In case of piezo stage if stage wearing is not a concern it can be set to as low as 1, which will increase system response in AOI tracking.

c) Optimize Configuration->ATF Parameter-> Far->Line width at 5x

Line width at 5x parameter determines the amount of laser intensity system is automatically adjusting. The larger value corresponds to larger amount of light. The advantage of using larger intensity is to increase linearity of m&g and remove the waviness of characteristic. The disadvantage is a more visible ATF laser illuminated line in a camera field of view and a second surface reflection in case of multi surface targets. To determine if Line width at 5x is set properly increase this parameter by 2 and observe M&G characteristic to see if linearity Is not improved. If both characteristics looks about the same then increasing its value further will bring no benefits to overall AF

d) Optimize Max Speed/Max Accel

Perform few AF tracking operation at different distances and make a note of overall time that took to get to focus. Next increase Max Speed/Accel parameters and see if AF time got improved. ATF-PZ is using Max Speed/Accel to estimate time delay necessary to wait before next motion is scheduled in AF tracking mode assuming a trapezoidal/triangular motion profile imposed by amplifier+piezo stage. By increasing Max Speed/Accel the overall motion delay is decreased and system moves quicker. If those parameters are adjusted higher then stage is capable of, the AF tracking algorithm starts oscillating because consecutive positions corrections are issued too soon before stage got chance to move.

e) Optimize P

P should be set as high as possible, but preventing oscillation. Typical strategy of setting P is to use 0.8 as a starting value. Once other parameters of the AF tracking are set and system is known to work and behave stable, start increasing P till system begins to oscillate around focus. At that point reduce P by 20%.

7) Adjust AOI tracking algorithm

ATF-PZ AO piezo stage motion capability needs to be enabled by turning the following option on:

a) Configuration->Parameters->Analog Output Position

This option fundamentally changes analog output function (AO). If off, AO indicate distance to focus which is useful if external servo controller is used. If on, AO is directly controlling piezo stage position and ATF sensor is acting as servo controller enabling AF/AOI tracking. Please save this option and reset ATF sensor when option is changed.

ATF-PZ AOI tracking adjustment should only be done once AT tracking is already established and works properly. See previous chapter 6) for the AF tracking verification steps.

b) Configuration->AOI Test->P asymmetry

This is a static adjustment that fine tunes Slope (um/DN) and P asymmetry to optimize both of them for a small motions typical for AOI tracking. This operation is performed with the help of AOI Test utility. See Fig 5-11.below

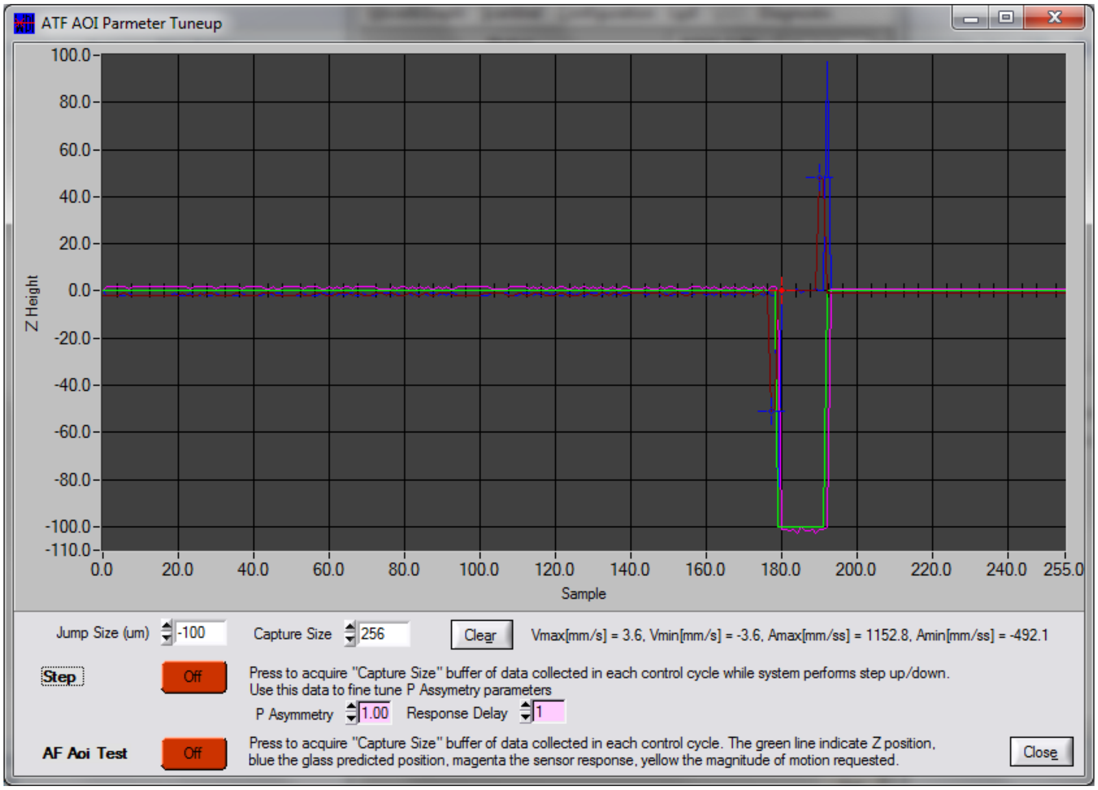


Fig 5-11 AOT Test utility screen. Please note a) blue line indicating target position; b) magenta line indicating measured distance to target; c) green line indicating the Z stage motion

AOI Test performs static (Step OFF) and dynamic (AF Aoi Test OFF) system tests. The static test executes a short square motion up and down and records among other things: a) Predicted target position (blue line); b) distance to target (magenta line); c) Z stage motion (green line). The time scale runs backward from right to left in units of samples corresponding roughly to 2 ms.
Please perform static test by pressing Step OFF button with default Jump Size (um) value calculated based on objective magnification. If your objective NA is higher than typical long distance objective Jump size should be reduced. In response system should generate a graph similar to one showed at Fig 7-1.

The objective of the static adjustment is to:

i. bring mid-section of the blue line (predicted target position) during the step the same value as before and after the step

ii. bring mid-section of the magenta line (distance to target) during the step the same value as green line (Z distance) during the step

Both conditions are equivalent. The rational for the test flows from the fact that target in focus has not been moved during a test, only stage moved by prescribed by system amount of motion. Test attempt to calibrate system to measure result of its own motion in order to generate proper estimate for amount of target motion during a dynamic test.
If the Slope (um/DN) is not calculated properly the resulting graph will have a shift as indicated on the picture below:

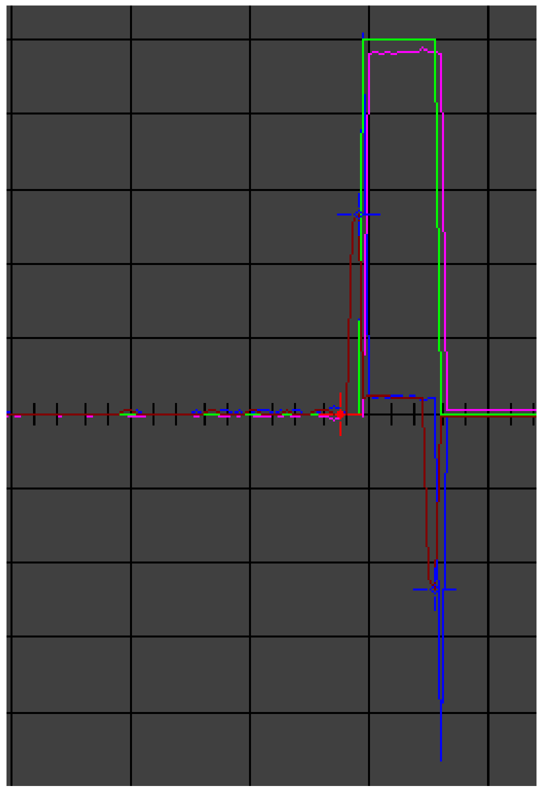


Figure 5-12. Please note that during a step blue line in its mid-section (disregarding transients around beginning and end of a step) is positioned higher then blue line before and after a step. At the same time magenta line (predicted position) is lower than a green line (actual position)

The process of adjusting Slope (um/DN) is an iterative one:

i. Click Step with positive Jump if P is positive or negative jump if P is negative
ii. If blue line at the center of the step is shifted from position outside the step decrease or increase the Slope (um/DN) parameter

iii. Click on clear the graph and repeat procedure at i) till amount of error is less than 5%

Once the process has been accomplished and Slope (um/DN) parameter adjusted the inverse of the motion (negate sign) need to be tested and P asymmetry parameter adjusted. Please execute same procedure but this time don't change Slope (um/DN) but change P asymmetry instead.

After successful adjustment the following graph should be captured: see figure 5-11 below:

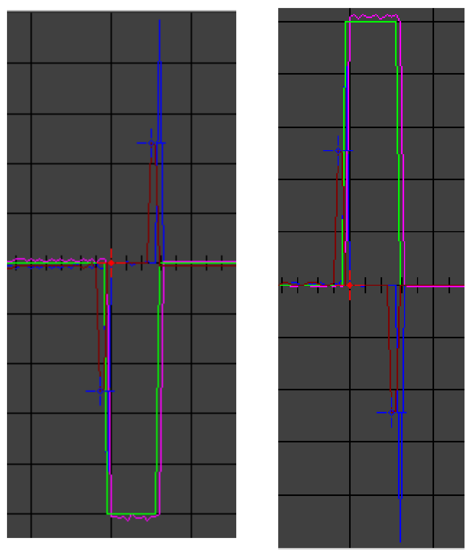


Figure 5-13. Please note that blue line remain stationary with upward and downward step.

The symmetry and the static response of the system have been adjusted.

c) Adjust Configuration->AOI Test->Response Delay

The most important parameter that is characterizing dynamic stage is a Response Delay. If this parameter is not taken into account while running PID close loop control overall system response needs to have lower P in order to avoid self-induced oscillations. In a current version of firmware a response delay is approximated with accuracy of sample time, i.e. 2 ms.

In order to estimate Response Delay do following:

i. Adjust Configuration->parameters->Aoi Avg Fast (1,0,0)
ii. Set Configuration->AOI Test->Response Delay = 1

iii. Click on AF Aoi Test OFF
iv. Capture graph to the file. Click Clear to erase graph
v. Repeat ii),iii),iv) with response Delay 2,3,4

The few graphs captured could be presented together as below seen in Fig. 5-14:

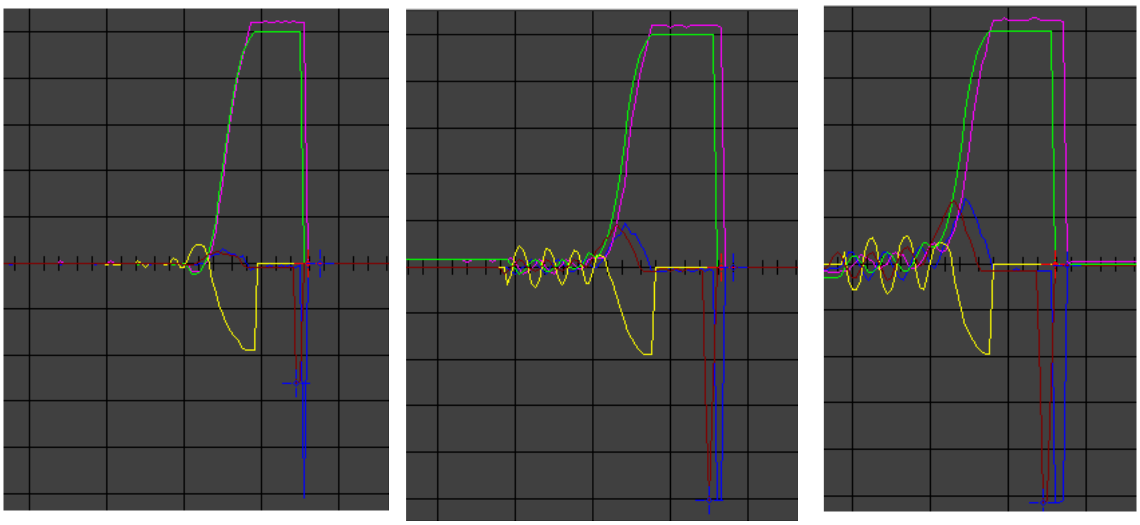


Figure 5-14. Three different value of Response Delay 1 (leftmost),2 and 3 (rightmost). Please note the amount of deflection in a blue line during the closed loop control phase is at minimum for Response Delay = 1, which is the best parameter for this MMS stage.

The best value of Response Delay is a one that is causing a smallest deflection in a blue line corresponding to a target predicted position during the close loop AF tracking portion (left side of the step).

In the Figure 5-14 the best value is depicted on the leftmost figure that corresponds to Response Delay = 1.

Based on experience so far MMS stepper motor stage have Response Delay at 1 or 2, while piezo stages have Response Delay of about 3 or 4.

8) Verify AOI tracking

The AOI tracking is best to be verified on the sample running across inclined target at the conditions as closely approximated a real situation.

While an AOI Test tool could provide inside as to algorithm operation the performance should be optimized based on quality of images acquired on the fly with a strobe illumination or based on independent method of measuring a height of a sample while AOI tracking was running. To start AOI tracking press main->AF AOI button. Press it second time to stop.

One useful criterion to quickly evaluate quality of AOI tracking is to observe a position of the laser line on the camera. This position is constant at the given distance from focus. Therefore if distance is preserved and AOI tracking works well position of the line is not changing during tracking. See Figure 5-15 below:

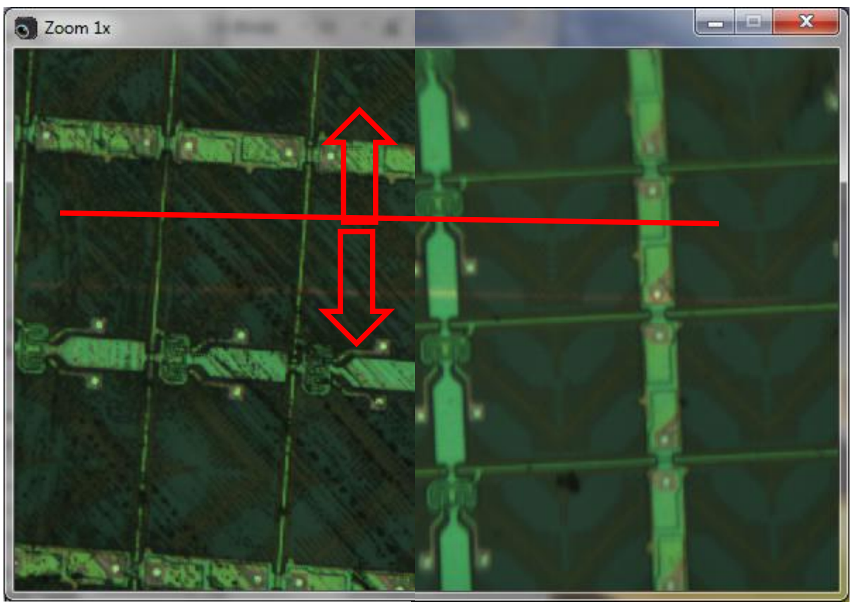


Figure 5-15. To images of target during AOI tracking: left target is stationary, right same target is moving along vertical direction. Please note that horizontal laser line falls at the same Y position indicating no Z shift.

Below will follow a description of parameters influencing AOI tracking.

1) Aoi Avg algorithms.
   Configuration->Parameters->Aoi Avg Fast (1,0,0); Aoi Avg Medium (2,0,0); Aoi Avg Slow (4,0,0)

Aoi Avg algorithm(M,0,0) is using an average of M (1,2 or 4) most recent samples as current position estimate. For smooth targets 1 is a best, while higher numbers tend to work better on diffused targets. This algorithm is fairly stable but requires small value of D in order to better track quickly changing target, since averaging samples increase control delay.

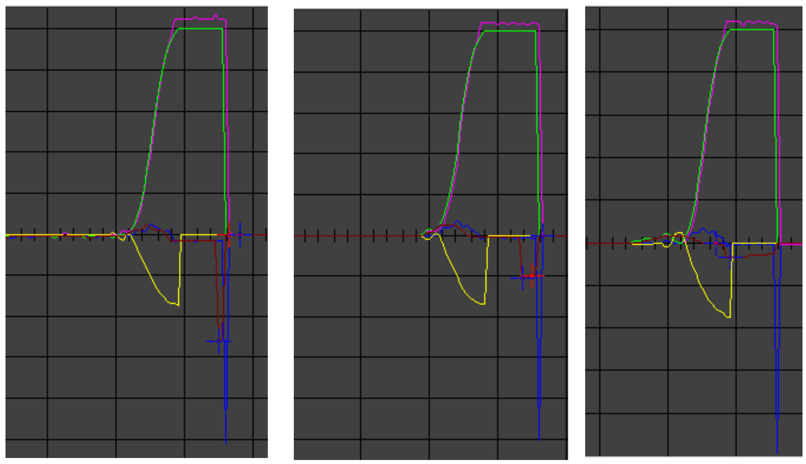


Figure 5-16: AOI Test on with 3 different Aoi Avg algorithms with averaging of 1,2 and 4 from left to right. 1 seems to be the best for this target because of smallest amount of oscillations

2) Aoi LinearAppx algorithms.
   Configuration->Parameters-> Aoi LinearAppx (2,5,2); Aoi LinearAppx (2,5,1); Aoi LinearAppx (2,10,3); Aoi LinearAppx (2,10,1);

Aoi Linear Appx algorithm (M,N,O) family is using linear extrapolation of N most recent samples (5 or 10) to calculate a current sample position as an estimate of O = 1,2 or 3 samples ahead. This algorithm works well on inclined targets and doesn't require D. Typically a value of P needs to be reduced below 0.7 to allow for stable operation.

3) Configuration->Parameters-> AOI D

D factor in PID control. However, given slow nature of changes of the microscope targets it is not proportionally to most recent change of distance to target but to most recent Z stage speed which acts as a low passed filtered distance to target change. Typically small value of 0.5 to 1 works the best in conjunction with Aoi Avg algorithms.

4) Configuration->Parameters->P

P factor in PID control. The best strategy is to set it to low value of 0.5 choose all other parameters and then gradually increase its value until control start self-oscillating. Lower it by 20% at that point.

5) Configuration->Parameters->In-Focus Range

As a general rule set to 1 since preventing continuous motion on piezo stage is not necessary since those stages typically don't have wearing out components (i.e. screw as in stepper motor). However, it may be advantageous to set In-Focus Range to same value as used in AF tracking. If low amplitude vibrations are observed in stationary case (AOI tracking on, target fixed, stage is jerked once and vibrations are not decaying) then rising In-Focus Range enables higher P then otherwise be possible since it creates brake on oscillations. This in turns benefits tracking in overall.

6) Configuration->Parameters->Max Vel/Max Accel

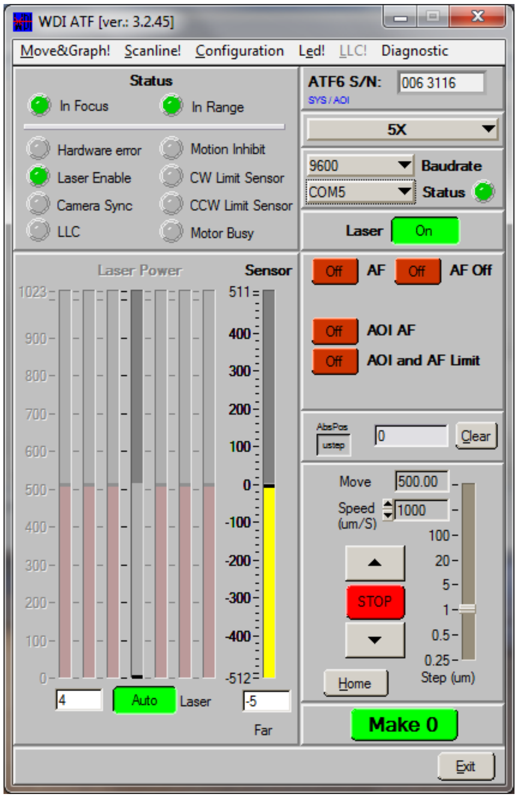
Best is to set those values to be larger than stage performance by 20% margin.
For a typical target it is expected that following parameter combinations should be tried first:

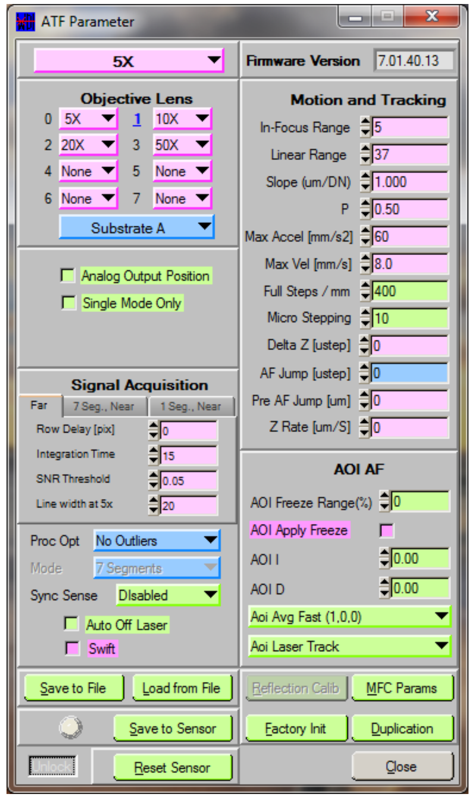
1) Aoi Avg Fast (1,0,0) + AOI D = 0.5 + P = 1.0
2) Aoi LinearAppx (2,5,2) + AOI D = 0 + P = 0.7
3) Aoi LinearAppx (2,10,3) + AOI D = 0 + P = 0.7

The D,P might change of about 200% and best parameters need to be adjusted experimentally

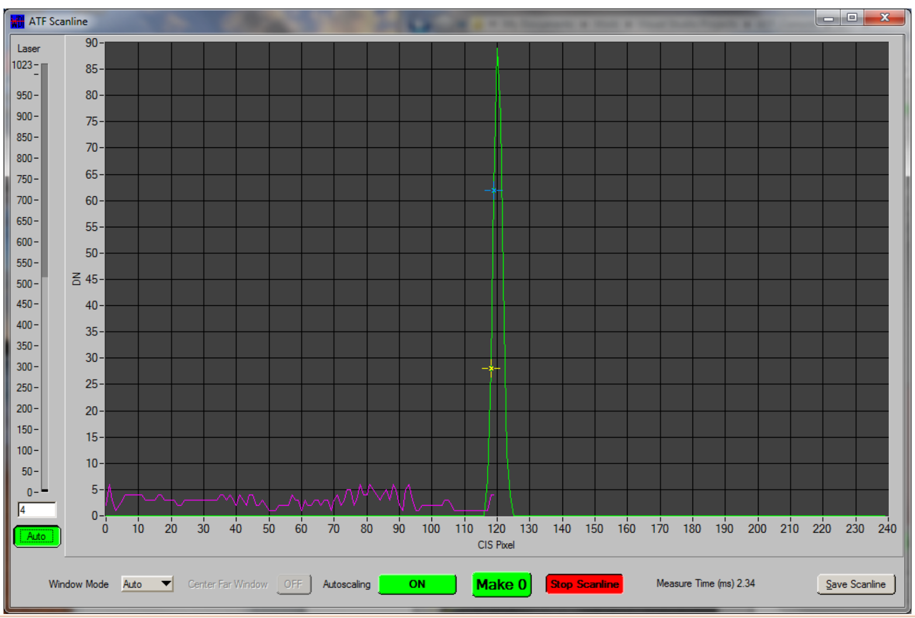
Appendix A - Typical Screen Shots:

Console Software and ATF Parameter:

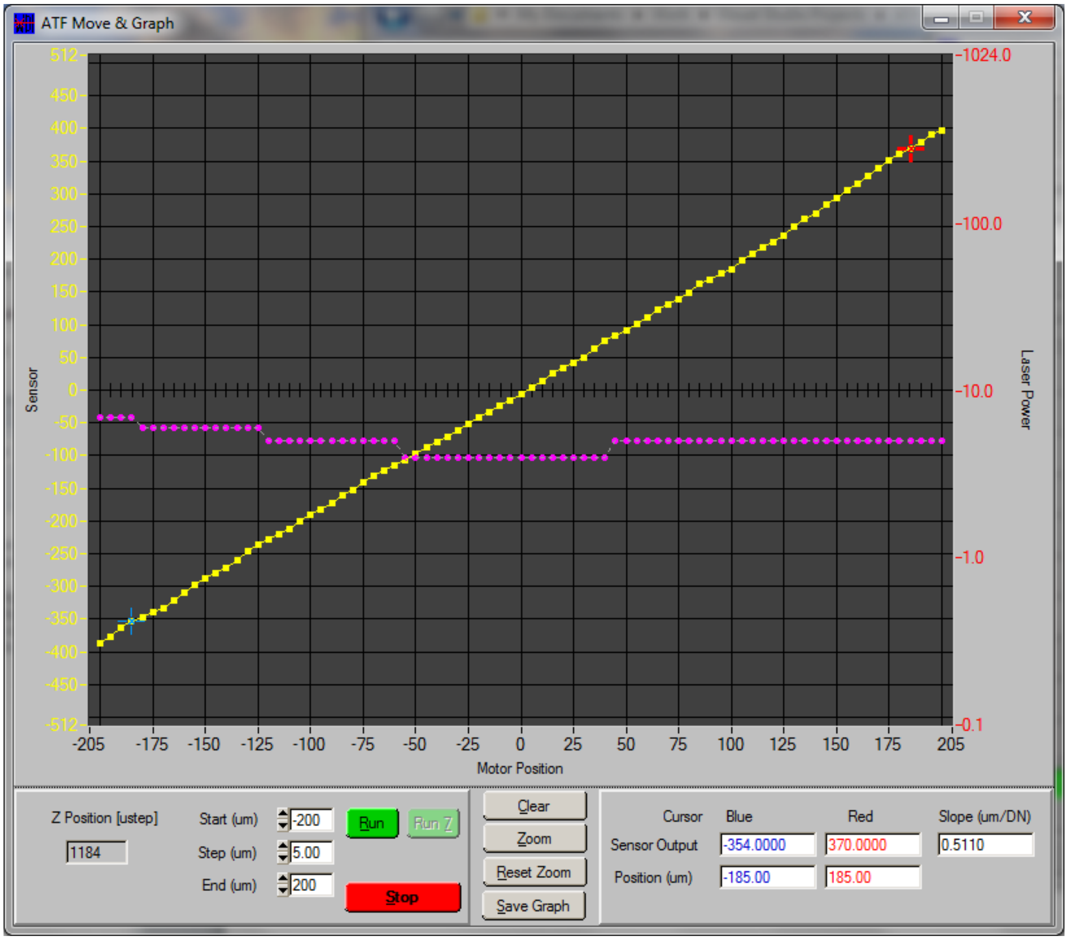




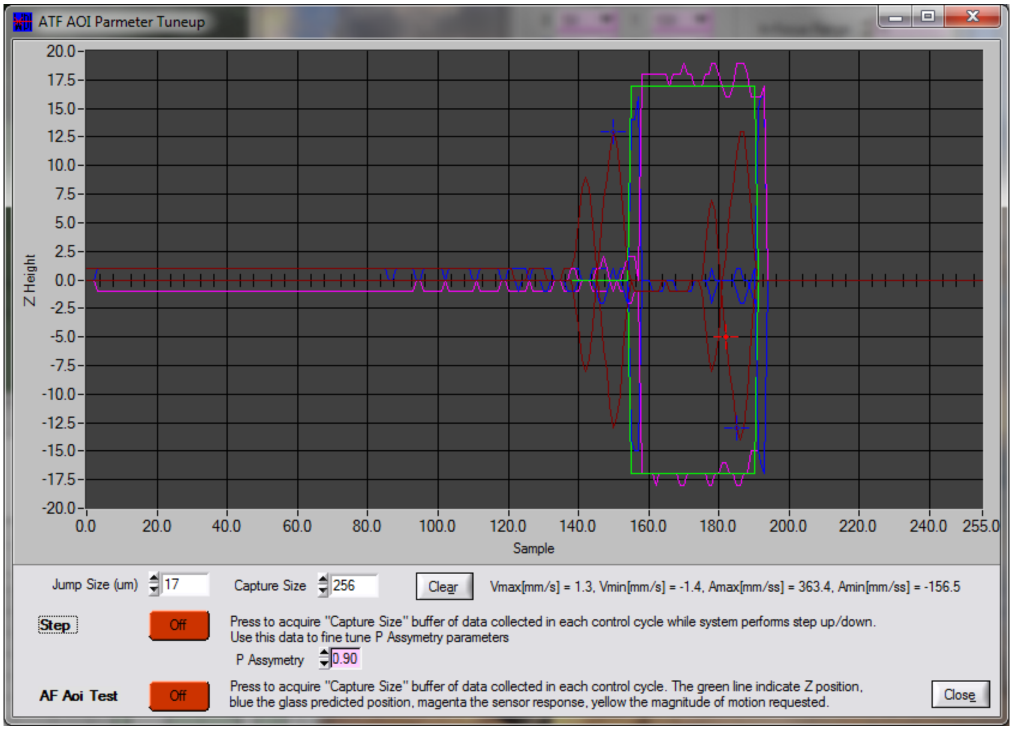
ATF Scanline:



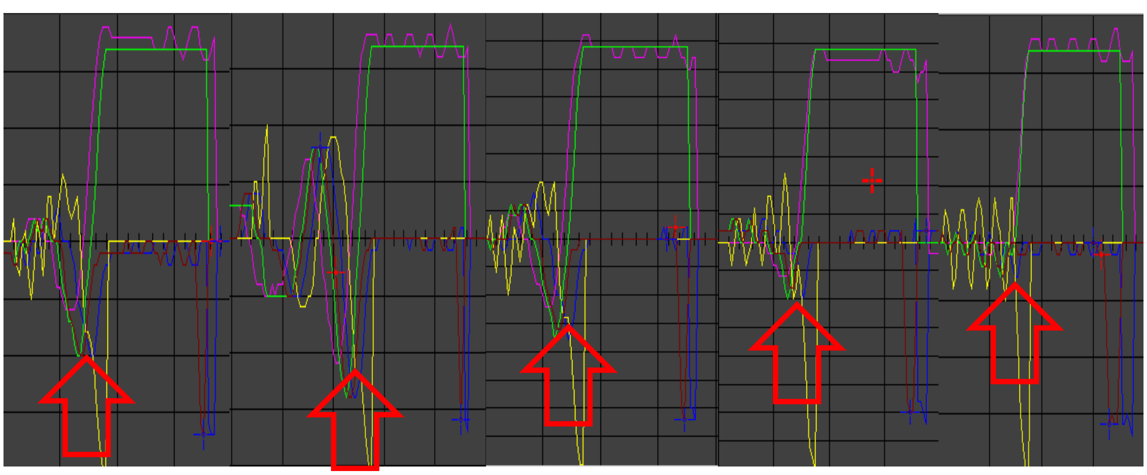
ATF Move & Graph:



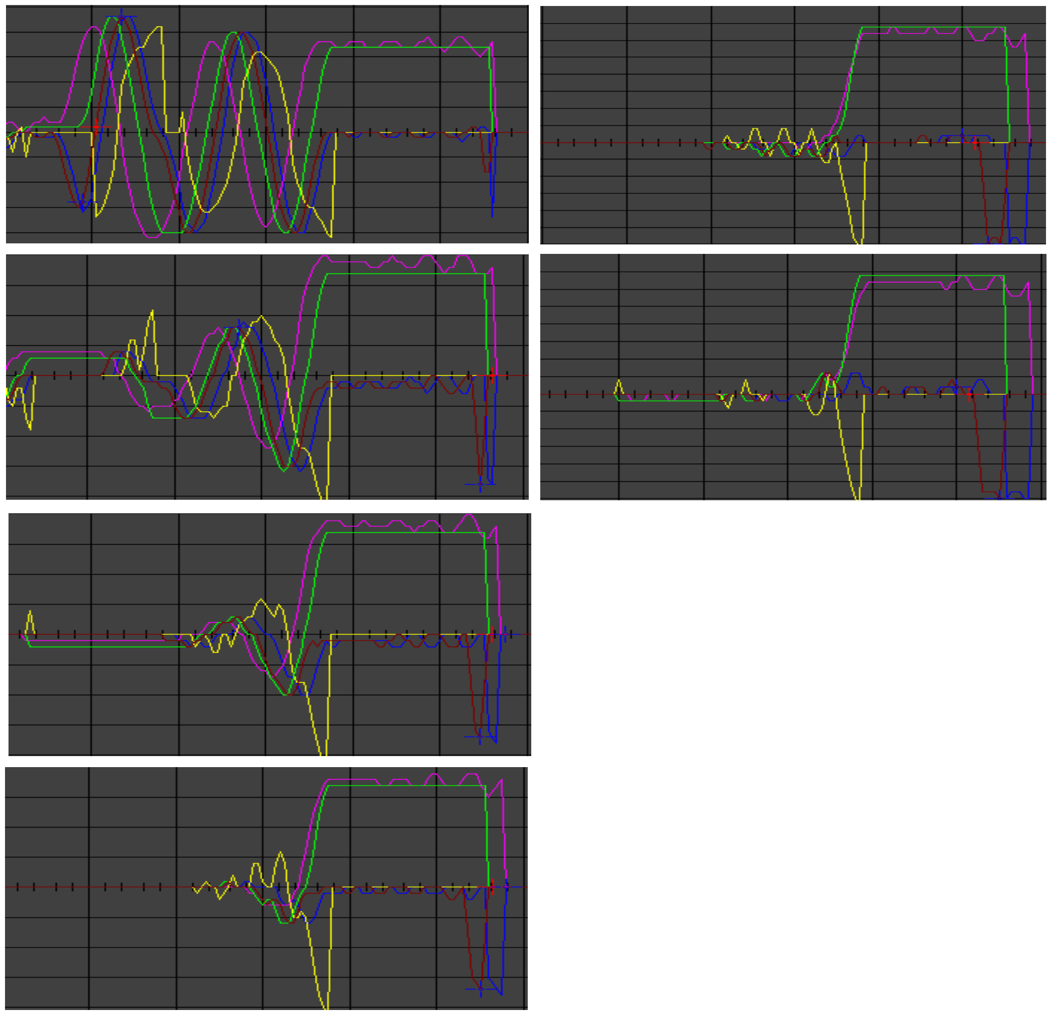
ATF AOI Parameter Tuneup:



ATF6-PZ Qioptiq piezo stage, Step/mm=7000, 20x objective, slope 0.05:



ATF6-PZ Qioptic PZ stage, Step/mm=7000, 20x objective, slope 0.05, response delay 1,2,3,4,5:

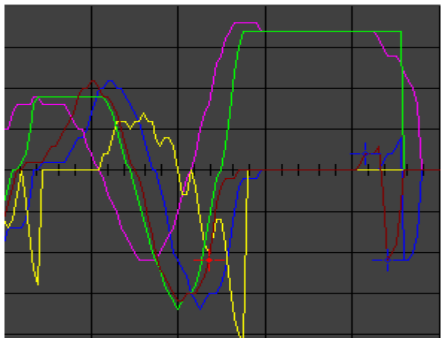


ATF6-PZ Qioptiq piezo stage, Step/mm=7000, 20x objective, slope 0.05, Aoi Avg (1,0,0), P=1.0, changing response delay 1 (top left) ,2,3,4 (bottom),5,6(right).

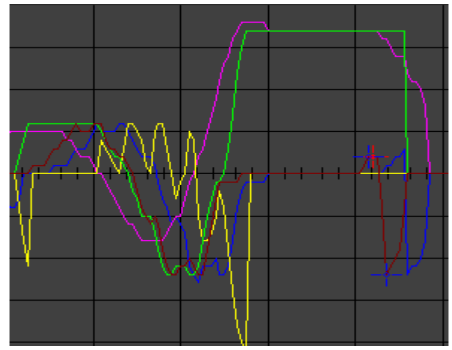
Please note that predicted target position (blue line) has a downward dip in the 1-4 cases and is rising up in case 5-6. This indicates that stage delay is larger than 4 and lower then 5.

Based on the above depiction response delay of 5 would be recommended.

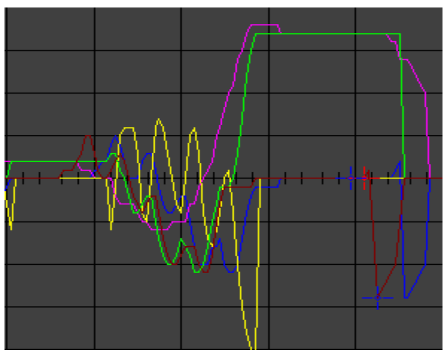
a)



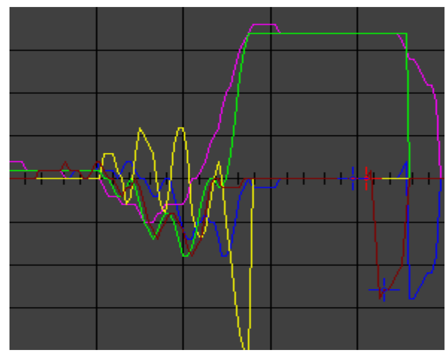
b)



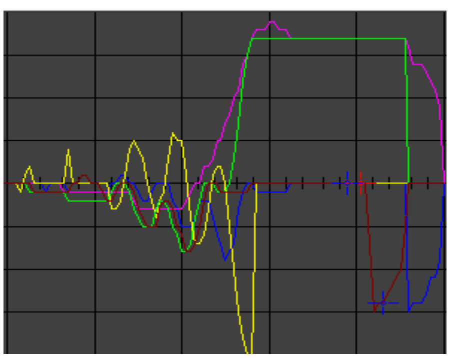
c)



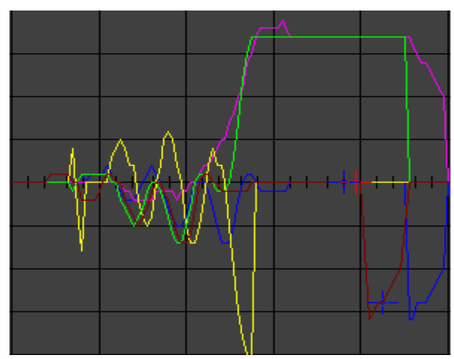
d)



e)



f)



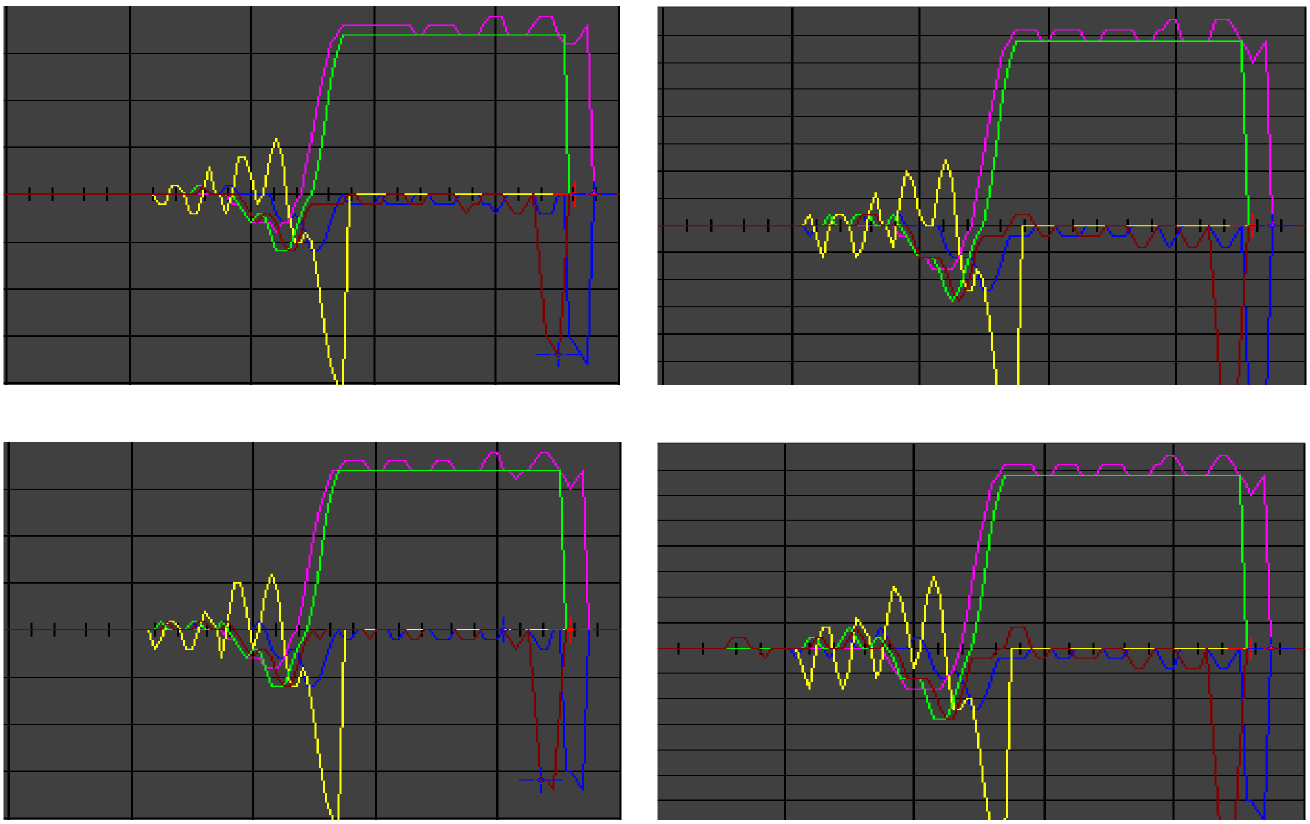
ATF6-PZ Qioptiq piezo stage, Step/mm=7000, 20x objective, slope 0.055, Aoi Avg (1,0,0), P=1.0, changing response delay to:

a) -4; b) -5;

c) -6; d) -7;

e) -8; f) -9;

In case of stage being controlled by 30DV50 closed loop position control with 200Hz low pass filter. One can observe that response delay of 9 is more appropriate (9*2.2ms = 20ms) comparing to half this value for open loop control. Generally it is better to dispense with piezo stage linearization build into amplifier with positional feedback and rely on absolute position measurement done by ATF sensor.



ATF6-PZ Qioptiq piezo stage, Step/mm=7000, 20x objective, slope 0.05, Aoi Avg (1,0,0), P=1.0, response delay = 4, changing response D = 0, 0.5, 1.0, 1.5

Chapter 6

SPECIFICATION

6.1. OPTICS SPECIFIC PERFORMANCE DATA

Table 6-1 Optical performance

Reference Data	Units	2x	5x	10x	20x	50x	100x
NA	um	0.055	0.14	0.28	0.42	0.55	0.7
Depth of Focus	um	+/- 91	+/- 14	+/- 3.5	+/- 1.6	+/- 0.9	+/- 0.6
Focus Repeatability	um	+/- 5.0	+/- 2.0	+/- 0.5	+/- 0.3	+/- 0.2	+/- 0.1
Focus Accuracy	um	+/- 15	+/- 6	+/- 1.5	+/- 0.9	+/- 0.6	+/- 0.2
Resolution	um	6	1	0.2	0.06	0.02	0.01
Linear Range [a]	um	+/- 3000	+/- 500	+/- 100	+/- 30	+/- 10	+/- 5
Capture Range [b]	um	+/- 5000	+/- 3000	+/- 1500	+/- 600	+/- 250	+/- 100

NOTES:

[a] Linear Range (LR)

The linear range is restricted digitally by the sensor controller. The linear range setting (as per spec above) has been found to be optimal for sensor speed and resolution. Extending LR reduces the resolution. The LR can be extended from its default setting at customer request.

[b] Capture Range

The specified capture range is valid if ***WDI***'s beam splitter is used for coupling the sensor and no additional beam splitters are placed between sensor and the objective lens. Additional beam splitters reduce light transmitted and received by the sensor and thus adversely affect the capture range. For magnification 2x, the capture range is restricted for thin glass. In the thin glass case and 2x magnification, the sensor is unable to distinguish top glass surface from the bottom one and will focus on the nearer surface. For magnifications 5x, 10x and 20x the system distinguishes top and bottom surfaces and thus focuses on the surface of user's choice. For magnifications 50x and 100x the surface recognition is not needed since the capture range is narrower than 1/2 of the typical LCD glass and the system are naturally pointing nearer to the desired surface.

6.2. GENERAL PERFORMANCE DATA

Table 6-2 General performance data

Parameter	Value	Unit	Comments
Output data rate	0.5	Khz	In tracking mode
Maximum processing delay	0.5	ms	Typical
Reflectivity adaptation delay	2	ms	Typical
Warm up time	<20	minutes	
Laser type	Semiconductor		
Laser wavelength	658	nm	
Laser safety	Class 2		
Working temperature range	15 to 24	deg. C	Guaranteed performance
Operating temperature range	10 to 40	deg. C	
Storage temperature range	-10 to 50	deg. C	
Humidity	Up to 80	%	Non-condensing
Weight	~ 0.3	kg	
Dimensions		mm	See foot-print drawing
Maximum cable length	20	m	

6.3. EXTERNAL REQUIREMENTS

Table 6-3 external requirements

Parameter	Value	Unit	Comments
Specimen reflectivity	1 to 99	%	Front surface
Glass thickness	>0.5	mm	
Back surface reflectivity	0 to 99	%	
Diffusing specimen	Yes		
Specular specimen	Yes		
Patterned / textured specimen	Yes		Particularly suitable for TFT arrays

6.4. PHYSICAL DIMENSIONS

6.4.1 ATF6 SENSOR UNIT

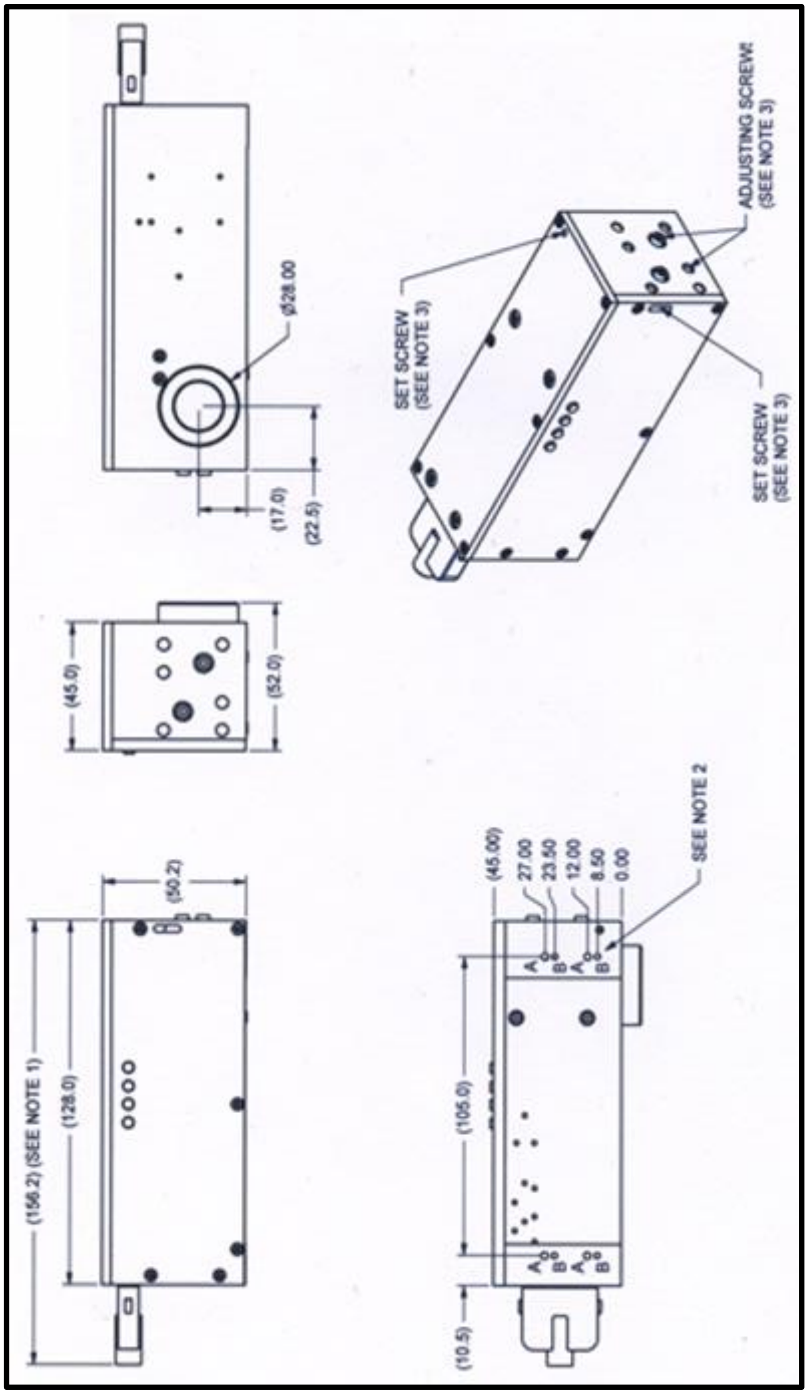


Figure 6-1 ATF6 Sensor Unit - Physical Dimensions

6.4.2 MCM+ CONTROLLER UNIT

The outside dimensions of the MCM+ are 106mm wide x 36mm high x 122mm long. This measurement consists of an 81mm wide x 31mm high x 122mm long enclosure and a 5mm thick mounting plate which is 100mm long x 106mm wide. The mounting plate has 4 mounting slots for M4 screws. Dimensions are shown in Figure 6-2.

Approximately 75 to 100mm of clearance should be left at each end of the MCM+ as working area for cable insertion and removal.

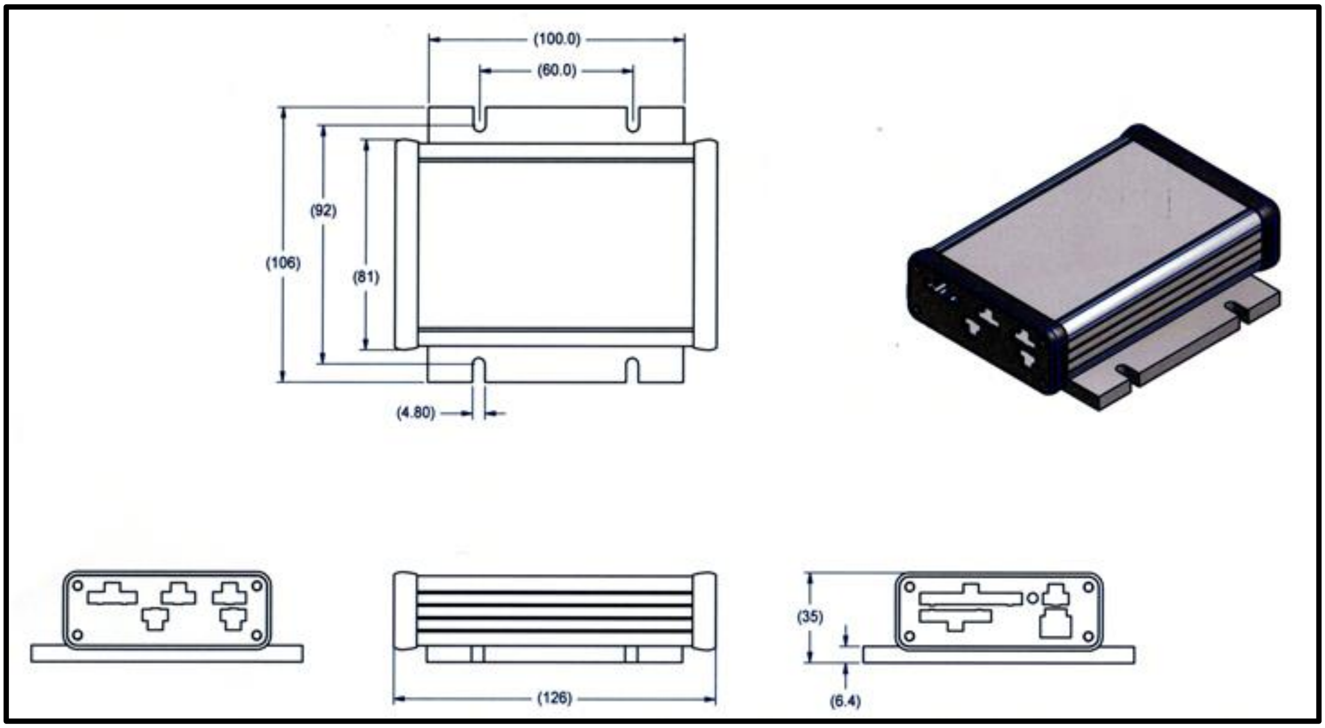


Figure 6-2 MCM+ Controller Unit - Dimensions

Chapter 7

SERIAL COMMUNICATION PROTOCOL

7.1. INTRODUCTION

This document reflects the serial communication functionality as the result of integration test of version 2.0 on July 2'nd. It supersedes earlier descriptions and summarizes the whole functionality rather than provide add-on extension.

The 2.0 protocol changes introduce the concept of configuration parameters and replace existing before configuration block commands. The testing and user commands are all changed.

The 2.0 introduces the motion loop functionality that is merged with sensor measurement functionality which is reflected in protocol commands.

7.2. REVISION HISTORY

Table 7-1 software revision history

Rev	Sw Rev	Date	Comments
1.0		June 20	First engineering units
1.2	0x0.3010351	June 20	Commands corrections to reflect testing
2.1	0x04010705	July 08	Configuration protocol rev 2.0 after integration tests
2.1c	0x04010705	July 12	Streamlining documentation
2.2c	0x04010705	July 12	U64 & U63 commands correction

Rev	Sw Rev	Date	Comments
2.2p	0x040107	July 12	Reflects removing Z control
2.3c		July 15	adding 85.
2.5c	0x04030805	August 5	Acceleration communication added
3.1,2,3	0x0301090D	September 5	Boot loader separation, BSA filter
3.3d	0x03030217	February 23	Incremental improvements
3.7	0x0307031F	August 5	Motion Activated Auto Focus (MaaF)
3.7a	0x03070323	August 5	Incremental improvements

7.3. PROTOCOL DESCRIPTION

Sensor is command driven as a slave device. Each command produces response. Commands and responses can't be interleaved.

By default RS232 operates at 9600 bauds, 8 data bit, 1 stop bit, no flow control. The speed can be increased up to 115200 by issuing baud rate configuration commands (see command U25).

The commands are divided in major sections:

- Data & Control commands intended to be used during normal sensor operation. Those commands are designed to be terse and optimized not to pose unnecessary overhead
- User configuration commands intended to be evoked before sensor and controller drive hardware in close loop. Those commands are designed for flexibility and have redundancy build in to assure communication error detection and recovery
- Debugging and testing commands intended to be used only during system setup, calibration and troubleshooting. Syntactically they are identical to configuration commands but could produce unexpected results if used in different circumstances then they were intended.

7.4. DATA & CONTROL COMMANDS

LASER DISABLE

Command: 0x82

Response: 0x82

Turns the laser off. The laser is enabled after sensor initialization unless the Laser Disable command is received or digital input laser cleared is asserted or digital input sync is asserted.

This command is equivalent to U2.

LASER ENABLE

Command: 0x81

Response: 0x81

Turns laser on after it was disabled with Laser Disable.

This command is equivalent to U1.

RS232 DATA REQUEST

Command: 0x85

Response: 2 bytes position and status response

Table 7-2 Data Respond Request

Bit	Description
Byte 0, Bit 0	In Capture Range
Byte 0, Bit 1	In Focus
Byte 0, Bit 2	Sync
Byte 0, Bit 3	Laser enable
Byte 0, Bit 4	Invalid Data
Byte 0, Bit 5-7	Bit 0-2 positional data
Byte 1, Bit 0-6	Bit 3-9 positional data
Byte 1, Bit 7	Unused (same as bit 9)

The position data is assigned a 10 bit number from -512 to 511 in engineering units, with 0 value indicating at focus.

The ***InCaptureRange*** and ***InFocus***, bits correspond to digital outputs described before. The ***Sync*** bit is asserted when the sensor detects the ***Camera sync*** input. ***Invalid Data*** is asserted when the sensor is unable to provide accurate results due either to a lack of proper configuration or a temporary transient event.

7.5. CONFIGURATION COMMANDS

Configuration commands consist of a number of tokens that follow session layer syntax carried on top of the transport layer. The session layer provides flexibility and allows a generic approach addressing individual registers mapped inside the controller. The transport layer facilitates communication redundancy and data delivery.

Currently only binary representation of the transport layer is proposed based on little endian number representation. Future versions are planned extending the transport layer to ascii notation making debugging with simple terminal possible.

The syntax is described in generic notation:

Syntax description

<……> - syntax token

| - alternative

(….) - optional (0 or 1)

'….' - literal

…. * - multiplicity (0 or more)

7.5.1 Transport Layer Syntax

Table 7-3 describes the structure of a serial message. Each message is confirmed with the ACK character. If a message is received intact the positive ACK is sent: a single character 'A'. If the message is determined to be incorrect, or executing commands described in the message results in an error then the negative ACK is sent: a single character 'N'.

The ACK character is sent after the content of the message has been parsed and requested operation executed. In most cases this takes a short time in order of ms (in case of register reads and writes). The exception is the 'Save' request (See command U5) that involves writing data into the device eprom which could last up to 7s.

binary packet = 'l' <payload count>< checksum > <packet>

Table 7-3 binary packet

Item	Size	Notation	Comments
coding scheme	1 byte	0x6c "l" - header start character indicating little endian convention	determines coding scheme for all the packets
payload count	2 byte	0 - 65535 - byte count	number of bytes in a message less 3 (number of bytes following payload count)
checksum	1 byte	complement 2 checksum	sum of all bytes is 0 if no violations
payload	payload count	payload data	session layer content

packet response = <ACK confirmation 'A'> | <NAK negation 'N'>

7.5.2 Session Layer Syntax

This is the generic syntax description. For clarity the following section details each parameter individually. Refer to chapter 0 for communication examples.

The Session Layer provides access to read and write registers made visible by the sensor. The host initiates a communication by attempting to read or write one of the registers. The sensor responds with ACK/NAK and optionally with a read response.

Each register is assigned a unique identifier. The register identifiers consist of 2 parts: bank id and parameter id. Registers are of a specified type and number of elements. There are 3 banks available: user bank ('U'), test bank ('t') and hardware bank ('f'). The Parameters ids consist of a number from 1-255. Example: U20. Registers also have a reading and writing privilege. Attempting to execute an operation without a granted privilege results with a NAK response. For a list of available registers refer to 7.5.4.1.

host packet ***= (<write command> | <read command>) ****

return packet ***= (< read response>) ****

The Host may send host packets at any time. If a message is understood, the sensor will respond with an ACK confirmation followed by an optional sensor packet. If the message cannot be decoded then the sensor will reply with a NAK negation.

read command ***= 'R' <register id tag> '0x7'***

write command ***= 'W' <content data>***

response to read ***= 'r' <content data>***

content data ***= <register data tag> (<data content>)***

data content ***= <number of bytes that is determined by data type & array num>***

The Host packet may be either a read command or a write command. Write commands are acknowledged with an ACK confirmation or NAK negation. Read commands will be followed by a read response.

register id tag ***= <bank id><param id>***

Table 7-4 register id tag

Item	Size	Notation	Comments
bank id	1 byte	0-255 – bank indicator 'U' - user 't' - test 'f' - hardware	parameter identifier is split into bank and id
parameter id	1 byte	0-255 – bank indicator	

The register id tag defines the register that is the target of the read command, and identifies the register that is a part of the write command and read response.

The 't' and 'f' registers are reserved for testing of the hardware/software and are generally not available to user programs.

register data tag ***= <register id tag>***
<data type>
(<array count> (<offset array from>))

Table 7-5 register data tag

Item	Size	Notation	Comments
data type	1 byte	Bits 0-3 = 0x7: Bits 4,5 data type: 0 – no data 1 – byte 2 – word 3 – dword bit 6 – 1 if array count follows (for 'R' and 'W'). If 0, array count is assumed 1. bit 7 – 1 if array offset follows (for 'R' and 'W'). If 0, array offset is assumed 0. – 1 if last data type (for 'r')	Specifies data type (bit 4,5) and next message element (6,7).

Item	Size	Notation	Comments
array count	16 bits	2-65535 – number of elements of type described in data type that follows	optional, only if data type bit 2 is set. 0 is invalid. 1 should not be send as array.
array offset	16 bits	1-65535 – offset of the first element in an array	optional, only if data type bit 3 is set. 0 Should not be sent as valid offset

The register data tag enhances the register id with additional information specifying data size, offset and type. This tag is used in the write command and read response packets, where it is immediately followed by the data content. It provides all necessary information allowing parsing and interpreting data content. It also specifies if data content is followed by the next token (data type, bit 7)

The data content is a binary array of characters encoding the array count of elements defined by the data type, which refer to the register identified by the register id at the offset location specified by the array offset. Data content elements are packed without any padding and are encoded in the little endian convention. The overall data content length can be calculated as the array count * data type size (See [Table 7-5]).

7.5.3 Communication examples

Example 1: Read Current Objective

Host: 6c 05 00 7f 52 55 32 37

6c - binary scheme little endian –'l'

05 00 - payload count, 5 in little endian notation

7f - checksum

52 - 'R' read request

55 - 'U' user bank id

32 - 50 Objective register id

37 - 3 – data type: dword (4 bytes)

- 7 - query code: current value

ATF6: 41 6c 09 00 db 72 55 32 b7 00 00 00 00

41 – 'A' ACK

6c - binary scheme little endian –'l'

09 00 - payload count, 9 in little endian notation

db – checksum

72 – 'r', read response

55 - 'U' user bank id

32 - 50 Objective register id

b7 – b = 3 + 8. 3 - data type: dword (4 bytes), 8 – last data type

- 7 - query code: current value

00 00 00 00 – 0 current objective

Example 2: Change Current Objective

Host: 6c 09 00 74 57 55 32 37 02 00 00 00

57 – 'W', write request

02 00 00 00 – 2 new objective value

ATF6: 41

Example 3: Read table of offsets for the first 5 objectives

Host: 6c 07 00 37 52 55 33 77 05 00

33 - 51 table of offsets register id

77 - 7 –=3+4: 3 data type: dword (4 bytes), 4- array count provided next

- 7 - query code: current value

05 00 – array count

ATF6: 41 6c 1b 00 7b 72 55 33 f7 05 00 00 00 08 00 00

00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

1b 00 – payload count 27, a whole payload is 27+3 = 30

f7 – f = 3 + 8 + 4. 3 - data type: dword (4 bytes) ,), 8 – last data type, 4 – array description

- 7 - query code: current value

05 00 – array count

00 00 08 00 - table offset 0 = 512 * 1024

00 00 00 00 - table offset 1

00 00 00 00 - table offset 2

00 00 00 00 - table offset 3

00 00 00 00 - table offset 4

Example 4: Write table of offsets for the objectives 2,3 and 4

Host: 6c 15 00 89 57 55 33 f7 03 00 02 00 00 00 08 00 01 00 08 00 02 00 08 00

f7 – f = 3+4+8. 3 data type: dword (4 bytes), 4- array count provided next, 8 – offset provided afterwards

- 7 - query code: current value

03 00 – array count

02 00 – array offset

00 00 08 00 – table offset 2

01 00 08 00 – table offset 3

02 00 08 00 – table offset 4

ATF6: 41

Example 5: Save all parameters

Host: 6c 05 00 d7 57 55 05 07

07 – 0 – no data to follow

- 7 - query code: current value

ATF6: 41

Example 6: Enable Z tracking

Host: 6c 05 00 d6 57 55 06 07

06 – Enable Z tracking register

07 – 0 – no data to follow

- 7 - query code: current value

ATF6: 41

Example 7: Disable Z tracking

Host: 6c 05 00 d5 57 55 07 07

07 – Disable Z tracking register

ATF6: 41

7.5.4 CONFIGURATION COMMANDS REGISTERS

7.5.4.1. SETUP REGISTERS

This set of registers is typically accessed only during initial sensor installation and hardware alignment. Once those parameters are determined, they should remain unchanged unless hardware conditions are altered.

Table 7-6 Setup registers

Register name	Register id	Size, Type, Permission	Description
Assign Magnification	U54 (85.54)	8, Word, read, write	Assigns magnification per an objective. Valid values for low 8 bits are: 2,5,7,10,20,50,and 100 corresponding to entries in t63 table. Write 0 to disable objective slot. Write 0 into current objective to reinitialize all setting to manufacturer default. The default values are: 5,10,20,50.
Preconfigured Magnification	t63 (116.63)	8, Word, read	Lists available objective magnification from pre-configured table. Valid values are: 2,5,7,10,20,50, and 100. User can reconfigure the set of objectives used in the application by assigning magnification (one of the values in t63) to the particular slot in the U54 table.
Current Magnification Selection	U49 (85.49)	1, Word, read	Currently the applied slot from Preconfigured Magnification table (t63). (exp: if 50NUV is current objective, then U49=4, while U50=5) Upon reading, reports magnification that corresponds to currently selected objective (U50).
Laser Pwm Write	U30 (85.30)	1, Word, read, write	Writes laser power value for currently used window. Laser value is expressed in relative range 1-1023.
Laser Pwm Read	U30 (85.30)	15, Word, read	Reads laser power from each of the 4 windows (far, left, center, right) and each of 3 laser dots (left, center, right) expressed in relative terms from 1-1023. In ATF4 laser power is available at offset 4
Register name	Register id	Size, Type, Permission	Description

Processing Option 3	U56 (85.56)	1, Byte, read, write	Non-persistant options that affect system functionality 32 – Allow Auto Window selection. When set system will optimize window mode for best measurement speed/accuracy. When signal is weak the far mode is preferred extending capture range. With more light being returned to the sensor center mode is used, closer to focus, left and right modes are relied on to increase accuracy. This flag is set for normal operation conditions. During system calibration Auto Window mode should be cleared as not to interfere with mechanical adjustment and alignment. This is done automatically by the ATF6_Test software.
Pwm Tracking Off	t7 (116.7)	0, No Data, write	Disables the laser pwm power tracking. In this mode laser power is determined by the values entered in U30 offset 0. This mode is used during initial system alignment.
Pwm Tracking On	t6 (116.7)	0, No Data, write	Enables laser pwm power tracking. The system adjusts the laser power for each dot accordingly to maintain a constant level of signal return. Under normal condition Pwm Tracking is enabled.
Software Version	U80 (85.80)	1, Dword, read	Access software version tag. Currently (7.1.23.05), (Jan., 2014)
BootLoader Version	U82 (85.82)	1, Dword, read	Version Tags extracted from BootLoader. Currently (7.7.10.12)
Sync Enable	U17 (85.17)	0, No Data, write	Enable sensitivity to sync D1.
Sync Disable	U18 (85.18)	0, No Data, write	Sync D1 is ignored
Register name	**Register id**	**Size, Type, Permission**	**Description**
Hw Status Flags	U45 (85.45)	1,Dword. Read	0x00000001 – HwOK 0x00000002 – HwCasErr 0x00000010 – HwLaserDioDisabled 0x00000100 – HwSyncDioAsserted 0x00000200 – HwSyncDioLastFrame 0x00000400 – HwSyncEnabled 0x00001000 – HwMotionZ (1)

			0x00002000 – HwMotionX (1) 0x00004000 – HwMotionY (1) 0x00010000 – HwMotionCWLimit (1) 0x00020000 – HwMotionCWLimitSense (1) 0x00040000 – HwMotionCCWLimit (1) 0x00080000 – HwMotionCCWLimitSense (1) 0x00100000 – HwMotionInhibit (1) 0x00200000 – HwMotionInhibitSense (1) 0x01000000 – HwWhistleCWLimit (1) 0x04000000 – HwWhistleCCWLimit (1) Note 1: valid only with WDI motor controller
Register name	**Register id**	**Size, Type, Permission**	**Description**
Hw Configuration	U48 (85,48)	1,Dword. Read	controller configuration capability 0x00000001 – Analog 0x00000002 – MtrCtlZ (1) 0x00000004 – MtrCtlXY (1) 0x00000008 – MtrMcm (1) 0x00000010 – Maaf (1) 0x00000020 –Mfc (1) 0x00000100 –Led1 (1) 0x00000200 –Led2 (1) 0x00000400 –Led3 (1) 0x00000800 –12V Reg (1) 0x00001000 –Epld (1) 0x00002000 –Whistle drive (1) 0x00004000 –Z drive (1) Note 1: valid only with WDI motor controller
Baud Rate	U25 (85.25)	1, Dword, read, write	Baud rate selection. Possible values are: 1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200. After reboot sensor is set to 9600 regardless of previous settings

7.5.4.2. CALIBRATION REGISTERS

These registers are typically accessed during objective setup and calibration.

Table 7-7 Calibration registers

Register name	Register id	Size, Type, Permission	Description
Assume 0 Position	U62 (85.62)	1, Dword, read, write	Assumes current peak position to indicate offset at 0. Used during 0 calibration. The command is issued when the sensor is at the best focus position. The current condition will be recorded as best focus.
Zero Offset	U51 (85.51)	[8][24],Dword, Read/write	Table of 192 elements organized as 8 groups of 24 elements for each objective. During the make 0 operation (U62) offset 13 in each 24 element group is set to indicate pixel peak position along the linear sensor. The element value is recorded with 10 bit extended precision (/ 1024 to obtain pixel position)
In Focus Range	U53 (85.53)	8, Dword, read, write	In Focus range is expressed in output units. If absolute measured position is less than this value the In Focus flag is asserted. The value is specified for each objective.
Linear Range	U52 (85.52)	8,Dword, read, write	The number of pixels peak shifts on ATF4 linear sensor corresponding to the end of linear range. Most objectives have set it to 30, but higher magnifications use 65 (50x) and 90 (100x). Change is not recommended. Table of 8 elements each corresponding to a different objective (indexed with U50)
Slope Conversion	U55 (85.55)	8,Dword, read, write	The numbers of micrometers in Z shift corresponding to single du change in sensor position (U41). This parameter is measured with move and graph utility and entered for every objective. Table of 8 elements each corresponding to a different objective (indexed with U50)
Step Conversion	U100 (85.100)	1, Dword, read	The number of full steps necessary to move the stage in Z motion by 1 mm. This calculation assumes that micro stepping is set to 1. (exp: if micro stepping is set to 10 and it takes 5000 microsteps to travel 1 mm, the Step Conversion should be programmed to 500).

Register name	Register id	Size, Type, Permission	Description
Micro stepping	U101 (85.101)	Dword, read, write	Microstepping, this field needs to reflect the actual pre-set values made on the hardware. The value must correspond to the stepper motor drive in use.
Gain Coefficient (1K)	U106 (85.106)	8, Dword, read, write	Gain multiplier * 1024. The typical values range from -1.0 to -0.2. The default value is 0.8 for SYS and 1.0 for SA. The sign indicates the direction of motion and may need to be reversed depending on stage wiring.
Max Acceleration	U107 (85.107)	8, Dword, read, write	The maximum stage acceleration in um/s*s. The Controller is capable of generating trapezoidal motion limiting the maximum acceleration on start-up and slowdown motion phases. The value is specified for each objective. The acceleration should be specified as high as possible for best system performance. Default value: 80000.
Max Velocity	U108 (85.108)	8, Dword, read, write	The maximum velocity in um/s with which the Controller should move the stage. The value is specified for each objective. Default value is 8000.
Motion Refinement Jump	U110 (85.110)	8, Word, read, write	The delta motion is expressed in microsteps executed at the end of the Tracking One Shot (U8) autofocus routine, if the current objective is designated as DUV. The offset is objective specific and the default value is 0. Executing the motion jump after the sensor reached focus addresses the problem of DUV objective color aberrations. In order to measure the value of U110, set the sensor U62 to 0 while the sensor scanline shows the narrowest peaks, make a record of the current Z position (U109) and then adjust the Z position to attain best focus. Use the difference in the Z position as U110.
B Threshold (1K)	t58 (116.58)	8,Dword, read, write	The relative threshold separating dot signature from background noise. Typical range 0.05 to 0.35. Default 0.1. The t58 threshold is preconfiguring for each objective. It should not be changed unless measurements are compromised with strong noise (i.e. reflection from bottom surface). In this case the threshold should be set higher. Setting t58 higher has an adverse impact on sensor linearity. Change not recommended.

Register name	Register id	Size, Type, Permission	Description
MFC motion setup	t172	5, char, read, write	Set of parameters configuring MFC internal Z drive: [0] – 0-0.5 Amp, 1-1.0 Amp per motor coil [1] – micro stepping configuration: 0 – 1 1 – 2 2 – 4 3 – 8 4 – 16 5 – 32 6 – 64 7 – 128 [2-4] – configuration bits. 0x17, 0x3B, 0x20 by default. Should not be changed w/o WDI advice.

7.5.4.3. AUTO FOCUS AND RESULT REPORTING REGISTERS

This set of registers facilitates typical sensor operation scenarios. It remains fully backward compatible with the ATF6.

Table 7-8 Autofocus and result registers

Register name	Register id	Size, Type, Permission	Description
Current Objective	U50 (85.50)	1, Dword, read, write	Currently selected objective. Values 0-7. New objective value determines current Zero Offset (U51), In Focus Range (U53), Max Acceleration (U107), Max Velocity (U108) and others.
Enable Z tracking	U6 (85.6)	0, No Data, write	Enable Z tracking. ATF4 acting as a Z controller will correct position error (position output, see U41) by applying proportional gain (see U106) on top of conversion factors (U100 & U55). Motion will not be executed if distance from focus is less than U53 (In Focus Range) and only after previous motion has been completed.
Disable Z tracking	U7 (85.7)	0, No Data, write	Disables Z tracking (U6,U9,U8,..). Default state after reboot
Enable Fast Z tracking	U9 (85.9)	0, No Data, write	Enable AOI Z tracking. ATF4 acting as a Z controller will correct position error (position output, see U41) by applying Z speed correction at every interrupt (appx 1ms) proportional to gain (see U106) and conversion factors (U100 & U55). Z speed will be set to 0 if distance from focus is less than U53 (In Focus Range).
Enable Auto Off Tracking Z	U8 (85.8)	0, No Data, write	Enables Z tracking, as per U6. In addition Z tracking is going to be turned off as soon as system recognizes In Focus Flag.
Save all parameters	U5 (85.5)	0, No Data, write	Commits all current parameter setting to the flash memory. Operation takes about 7s and ACK response to this command is delayed accordingly.
Position Output packed	U41 (85.41)	1, Word, Signed	Position output register reports the same as command 0x85 (See chapter 7.4)
Analog Output Out	U40 (85.41)	1, Word, Signed	Analog Output register reports current value written to ADC. Value is in range of –U60[0] to

			+U60[0]
Register name	**Register id**	**Size, Type, Permission**	**Description**
Analog Output Range	U60 (85.60)	2,Word, read, write	[0] – Maximum range of change of the U40. Default value 1495 corresponding to 8V [1] – Zero Offset. Default value 2048 corresponding to 0V
Status and Execution Flags	U20 (85.20)	1, Word, read	Binary flags combination representing system status: 0x0001 - HwOK. Hw has been downloaded and checked OK 0x0002 - SwOK. Sw initialized properly. Parameters had been found 0x0004 - Not used (ATF6 MAAF) 0x0008 - ZMotion. Z stage motion is in progress 0x0010 - LaserOn. Laser is enabled. If cleared, digital input Laser enable is off, software command U2 has been issued or system encounter initialization problems (HwOK,SwOK are cleared) 0x0020 - LaserDisableMode only set when digital input Laser enable is off 0x0040 - SyncEnable. If on, asserting Camera Sync digital input will turn laser off. 0x0080 - SyncOn. Camera Sync digital input is asserted. Can only be used if SyncEnable is on. 0x0100 - Always 1 0x0200 - LaserPwmTrack. If on, sensor is adjusting laser power to maintain constant dot height value. If off, sensor laser power is determined by U30. 0x0400 - ZTracking. Sensor is scheduling Z motions to bring sensor to focus. 0x0800 - NearWindow. If on, sensor is operating in left, enter or right window with 3 dots available (set after t10). If off, sensor operates in far mode (cleared after t11) 0x1000 - InCaptureRange. Sensor recognizes presence of the glass. 0x2000 - InFocus. Sensor measured position falls

			within InFocusRange (see U53) 0x8000 - CachedData. Sensor is reporting same position as last successful measurement that occur no more than 4 measurements ago.
Register name	**Register id**	**Size, Type, Permission**	**Description**
Error Code	U42 (85.42)	1, Dword, read	Returns error code from the most recent auto focus calculation. Valid codes are: AfStatusOK = 0, - results has been calculated properly AfStatusLowIntensity = 2, - results tmp unavailable due to laser pwm control AfStatusFailed = 5, - results can't be calculated, error AfStatusGlassOut = 6, - no signal detected AfNotAvailable = 11 - results tmp unavailable
Error Status Position	U42 (85.42)	3, Dword, read	Table of 3 consecutive values: Error Code (U42), Status (U20), Position (t41) can be accessed in one instruction instead of issuing 3 separate calls.
Enable Laser	U1 (85.1)	0, No Data, write	Enables laser. Laser power is set depending on value of LaserPwmTrack. If on, sensor will adjust value automatically starting from value used before laser was disabled. If off, U30 value is loaded.
Disable Laser	U2 (85.2)	0, No Data, write	Disables laser. Laser is turned off.
Abs Z Position	U109 (85.109)	1, Dword, read, write	On read, reports Z position calculated by sensor as a sum of all motions. Write allows Host to reset position to desired number. Position is expressed in microsteps.
Z Move	t100 (116.100)	1, Dword, read,write	On write requests sensor to execute motion specified number of microsteps. If command returns Ack motion was scheduled. If command returns Nak, various reasons might prevent motion, such as: system is busy executing current motion, limit switches are engaged, hardware or software failure.
LED PWM	U130 (86.130)	1,Word,read,write	current Illumination pwm value (0-100)

Register name	Register id	Size, Type, Permission	Description
LED Current	t131 (116.131)	1,Word,read,write	LED current (3-80) corresponding to 30-800 mA. The LED controller will initiate current calibration.
Register name	**Register id**	**Size, Type, Permission**	**Description**
Whistle Cmd	f100 (102,100)	64.char,read, write	Commands passed directly to control whistle drive for LLC

7.5.4.4. TESTING REGISTERS

Set of registers that might be helpful during diagnostic and troubleshooting.

Table 7-9 Testing registers

Register name	Register id	Size, Type, Permission	Description
Sync On	U3 (85.3)	0, No Data, write	Enters Sync mode. In sync mode AF measurements are suspended. The last valid measurement is being reported until sync mode is exited. The Z control unit is not going to correct position until sync mode is removed.
Sync Off	U4 (85.4)	0, No Data, write	Normal operating state, sync is de-asserted.
Disable Motion	U16 (85.16)	0, No Data, write	Stop motion immediately. In order to enable motion the U15 need to be issued. Might be used as an emergency stop
Enable Motion	U15 (85.15)	0, No Data, write	Z motion is enabled. Default after reboot.
DIO flags	t116 (116.116)	1, offset 8, Word, read	Reports DI status: 0x0001 - laser enable DI 0x0002 - sync DI 0x0010 - MIV DO 0x0020 - InFocus DO

7.5.4.5. SPECIAL FEATURE REGISTERS

Set of registers supporting special features that may not be available in all sensor models.

7.5.5 OBJECTIVES CONFIGURATION

Manufacturing releases sensors with objective 0 configured according to the data presented in Table 7-10.

Table 7-10

Parameter	Value	Register	Comments
Objective	0	U50	
Zero position	512000	U51	might vary slightly, depending on optical calibration
InFocus range	6	U53	
Microstepping selection	0	U105	
Gain Coefficient	-400	U106	
Max Velocity	550000	U107	Reflects stage characteristic, should be individually
Max acceleration	40000	U108	set for each hardware.

In order to programmatically configure sensor to operate with other objectives then 0, it is important to properly set all the 51-53,105-108 registers for the new objective before requesting objective change. Failure to do so might result in unexpected sensor behaviour which could require sensor reboot.

As an example below is a proper sequence to program operation for the second objective:

a. Write 512000 into register U51 offset 13 (set Zero Offset half way)
b. Write 6 into register U53 offset 0 (In Focus Range to 6)
c. Write 8000 into register U107 offset 0 (Max Acceleration 8 mm/SS)

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d. Write 80000 into register U108 offset 0 (Max Speed 80 mm/S)
e. Write 0 into register U50. This selects objective 0 for the operation which had been programmed with steps a. through e.

Note: The exact sequence of the instructions steps a. through e is not important. **It is important to set all of them before selecting objective 0.**

In order for the programming to be permanent, select write with no data to U5 (see example 5) which preserves current parameters with in internal flash. (write 0 to U50 before issuing U5 if you expect sensor to resume operation with objective 0 after reboot).

Chapter 8

WLOADER APPLICATION

8.1. INTRODUCTION

This document describes usage and installation of the ***WLoader*** program provided by WDI-Device for the purpose of upgrading ATF6 sensor application firmware and boot loader code.

WLoader communicates with ATF6 sensor over serial RS232 connection. ***WLoader*** runs on Windows 2000/XP platform and requires Microsoft .net Framework 2.0 or higher. (See "Installation" section) This document is written based on Windows XP.

WARNING:

It is important to read the entire document before running the *WLoader*. Misuse of the *WLoader* program can lead to the incapacitation of the ATF6 sensor and a need to return the unit for repair.

Troubleshooting of the failed loading is not described in this document.

8.2. WLOADER INSTALLATION

WLoader distribution kit consists of the "***WLoader***Setup_XXXX.msi" file that contains:

- "WLoader application notes" document
- WLoader.exe executable
- BootTestCmd.xml boot loader configuration commands
- App_XY.wlf Application firmware file
- BootLoader_53.bin BootLoader file.
- AppTestCmd.xml application configuration commands
- AppTestScript_App_XY.xml loading command script

8.2.1 PREREQUISITE

Before attempting installation assure that:

1. PC you intend to install WLoader is running Windows XP service pack 2.0 or higher. Go to "Start->Control Panel->System->General" page. The Windows version and service pack level is displayed there.
2. PC you intend to install WLoader is equipped with a serial port. Find out the port name. Go to "Start->Control Panel->System->Hardware->Device Manager". Under "Ports(COM & LPT)" tree

   node you will find list of all serial ports. Write down the port name you intend to use. E.g. COM6.
3. Windows XP is running .net Framework 1.1 or higher installed. Go to "Start->Control Panel->Add and Remove Programs". See if the "Currently installed programs" contains the following items

a. Microsoft .NET Framework 1.1

b. Microsoft .NET Framework 1.1 Hotfix (KB886903)

   Alternatively, the higher version of framework could be installed. If this is not the case download and install latest framework from Microsoft msdn site. The exact path might differ. Check: http://www.microsoft.com/downloads for "Microsoft .NET Framework Version 1.1 Redistributable Package". As of this writing package is available at this link below. http://www.microsoft.com/downloads/details.aspx?FamilyID=262D25E3-F589-4842-8157-034D1E7CF3A3&displaylang=en.:

4. The user must have System Administrator privileges. Go to "Start->Control Panel->User Accounts". Verify that your account is labeled as "Computer administrator"
5. Ensure that at least 10MB free of disk space and at least 20MB of available memory is available.

8.2.2 INSTALLATION STEPS

Installation requires the following steps:

1. Copy the "WLoaderDistributionRelX.X.zip" file into directory of your choice and extract all the files.
2. Run WLoader.exe file at the directory WLoader is loaded. The Wloader window will be displayed - Figure 8-1.
   - This step has created the "\HKEY_CURRENT_USER\Software\WDI-Device\WLoader\3.2.0.1" registry path where all your session settings are preserved.
3. For the convenience you may choose to create a shortcut on a desktop by right mouse clicking on WLoader.exe and dragging it to the desktop. Select "Create shortcut" from pop-down menu.

The installation is complete.
If an error message is displayed, verify that the Microsoft Framework is installed properly.

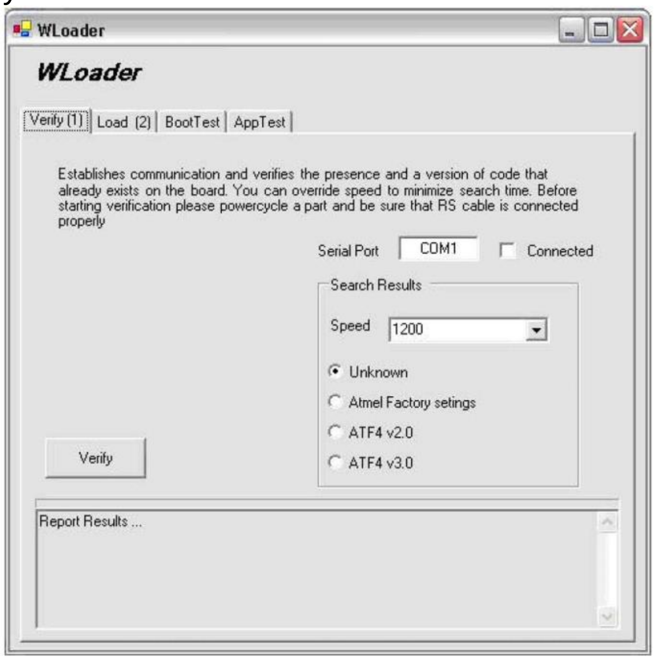


Figure 8-1 Remote tab

8.2.3 RELOADING ATF6 FIRMWARE

The WLoader software must be installed properly before ATF4 Firmware can be reloaded.
WLoader is able to automatically detect the current version of installed firmware and BootLoader. It is important to execute the Verify(1) first stage of the loading process before commencing a Load(2) second stage. This assures that correct loading procedure is executed.

During installation the user can choose to download both the BootLoader and the Application or only the Application as required. If the BootLoader version agrees with currently supplied BootLoader, file then BootLoader should not be reloaded. Reloading the BootLoader code always carries a risk of leaving the sensor boot sector with incomplete data (ex: the cable has been removed after an erase was issued, and before all data had been restored). If that happened, the sensor must be returned for service repair. However, reloading the Application can't cause such severe sensor malfunction. Even if Application section is damaged, WLoader will be able to establish connection with BootLoader and attempt to reload the Application.

Reloading the Application requires assistance from the loading command script defined in AppTestScript_App_XY.xml file. Script execution allows to you to save values of selected parameters before loading is performed, and restores those parameters afterwards. This process assures that the sensor configuration is proper after application was reloaded.
Script also sets the default values and enables the sensor functionality that is by default disabled at the end of the loading. Instead of using a script file, a trained user has an option of selecting parameters individually using AppTest page where they can be read and written. This option is generally discourage for customers, and related details and procedures are beyond of scope of this document.

8.2.4 PREREQUISITES

Ensure that the following conditions are met:

- Sensor is connected with the RS232 cable
- WLoader is installed

8.2.5 RELOADING BOOTLOADER

- Loading BootLoader is omitted from this version

8.2.6 RELOADING APPLICATION

- Power cycle sensor
- This can be done by removing the cable directly connected to sensor, or by turning off the power to the breakout box. Alternatively, the 'Z' can be sent via serial communication if sensor is version 3.0 and higher
- Run ***WLoader*** application.

8.2.7 Verification

The main screen should be presented displayed in Figure 9-1.

- Provide "Serial Port" name and select "Connected". If port could be opened then the Serial Port" field is going to be grayed out. In order to modify it again you need to uncheck "Connection"

- By default Speed is selected to 1200. ATF4 firmware starts at default at 9600. You can change "Speed" to 9600 to make verification run quicker, since sensor had been reset before.
- Select 'Verify' button. The verification process is going to take place. During this time WLoader is going to probe all the speeds from the selected one up and attempt to communicate. If ATF4 sensor is connected properly the verify process is going to succeed. You should receive confirmation as displayed below:

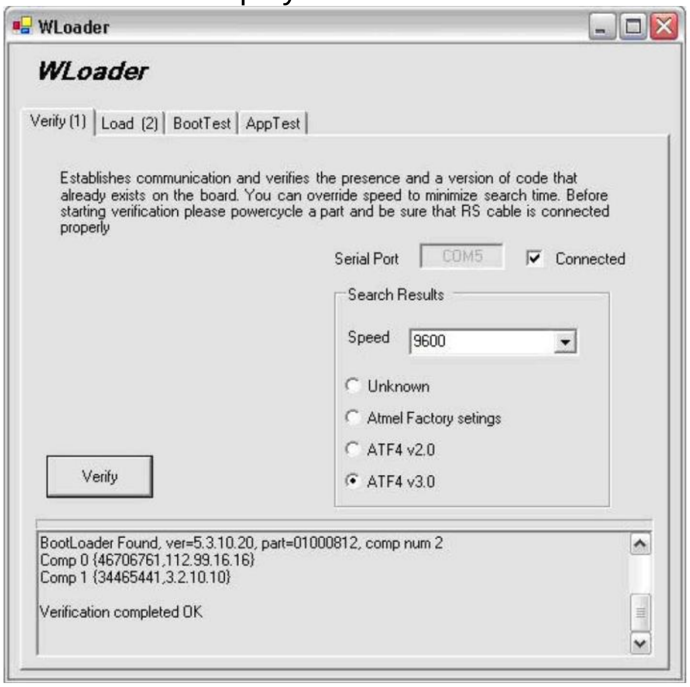


Figure 8-2 WLoader Window - Verification

Observe the message ***"Verification completed OK"*** is present. Also the **ATF6 v3.0** is being detected. The version v2.0 and lower require a BootLoader upgrade. Version v3.0 require BootLoader update if BootLoader version is lower the 5.3. Boot loader version is being printed as shown above shown in Figure 8-2. In the above example BootLoader version 5.3 compiled on Oct 10 is found.

Warning: You need to reload BootLoader if BootLoader is not found (v2.0) or Bootloader version is below 5.3. Failing that will leave the sensor incapacitated.
During verification, the "Verify" button will change to "Cancel". Pressing this button invalidates the verification process and it must be repeated as many times as needed.

8.2.7.1. Loading

1. Select the *Load(2)* tab.
   - You need to input "Payload load" settings properly before starting the load.
2. Click on the "*Load…*" button right to "*Load Payload(wlf,rbf)*". Select *App_XY.wlf* file that can be found on the distribution directory.

3. Select checkbox to the left indicating that you intend to download application file

4. Click "*Load…*" button to the right of "*Param Script*". When OpenFile dialog pops up select *AppTestScript_App_XY.xml* file that is found on your distribution directory.

5. Select "*Run*" to indicate that script file is being applied

6. The "*Load Speed*" is selected by default as 19200. The maximum loading speed is 115200. **Do not use any speed that was tested and approved**.

7. At the end of this process the window will display the current loading information as shown in Figure 8-3.
   - Note that only when the proper *.wlf file is selected the file details are going to be presented as shown above. In this example the Comp1 contains application version 3.4 (indicated as 3040)

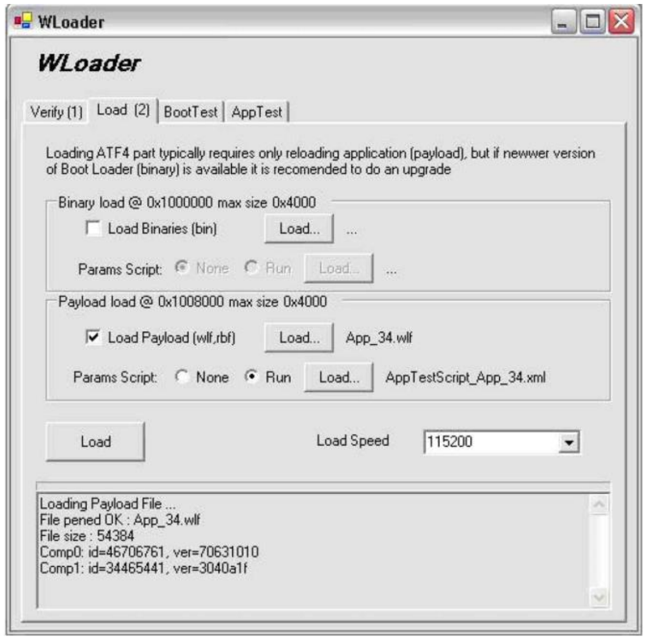


Figure 8-3 WLoader window - Load (2)

8. Select "Load"
9. This starts a whole process that involves number of steps, execution scripts data and resetting boards' number of times. At the end you should be presented with indication that reloading new version had been successful as shown in Figure 8-4.

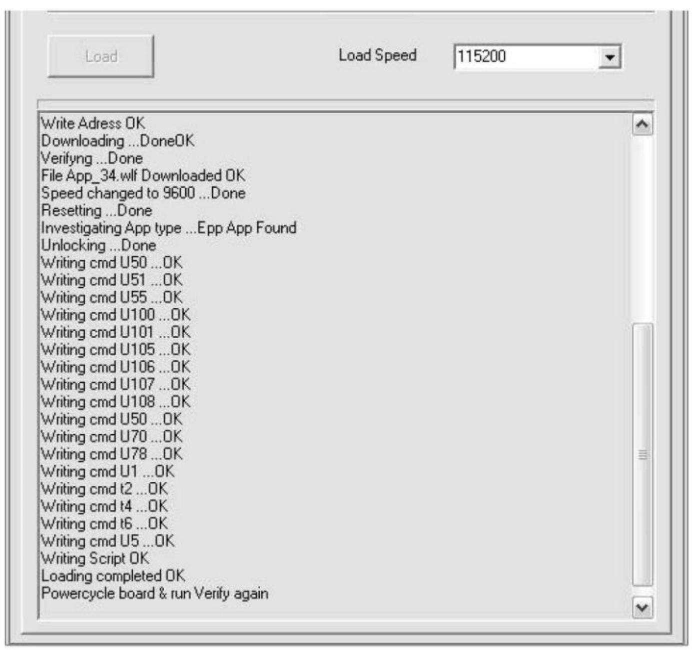


Figure 8-2 Even Viewer

- Observe the event “Loading completed OK” message.
- During load process you should wait for final results and don’t interrupt software operation. There will be long pauses at times that are not necessary indicating operation malfunctioned (Writing cmd U5 … is one of them). Be patient.

  Warning
  Pressing “Cancel” during loading can leave firmware with partially written data that could lead to loss of configuration parameters.

10. Follow the last advice printed and power cycle the board again. Wait for 5 seconds or more to give software sufficient time to boot.

11. Go back to the “Verify(1)” page and select “Verify” again. This will redo the verification process. You should see a newer version of the application listed at the end of verification. If this is not a case, loading had failed

12. Power cycle the board again and let application boot

13. Exit WLoader application by clicking on [x] in upper right corner

14. The sensor should return to normal operation. This is going to be indicated by laser power being adjusted. If there is no laser light visible, the loading of the application has failed.

15. Run Console software and verify normal operation.

    Application reloading/loading has been completed.

8.3. REMOTE WLOADER REMOTE ACCESS

Remote WLoader application permits remote access to the sensor over the network. This capability is introduced in order to facilitate remote troubleshooting that permits engineers from WDI to inspect Sensor setup and analyze in real time data that would be difficult and prolonged to obtain otherwise

In order to enable remote access execute the following steps:

- Connect the serial port of the ATF6 sensor.
- Switch to "Remote" tab.
- Set the port number, and click "Allow Remote UDP Serial Access".
- If your computer connects to internet through a router, you must let the router forward (port forwarding) the UDP port number to your computer (it is better to set your computer with a static IP address). Usually you can use a web browser to access the router configuration. Consult router manual.
- Check the firewall setting and ensure the UDP communication through that port number is allowed. (set up an exception)
- Make a note of the external IP of your system. To find your IP address, you can go to this website: http://www.ipaddressworld.com/
- Let WDI engineers know the port number and the IP address.

Figure 8-3 Remote Wloader

Chapter 9

WDI TEST SOFTWARE

9.1. INTRODUCTION

The 'WDI Test' software (***ATF6_Test***) is to support validation, characterization, and functional test of the ATF6 sensor. The source code is also supplied (copied upon installation) as a sample code.

9.2. USAGE

9.2.1 Start up

On start-up, the software needs specification on the COM port where the sensor is connected. By selecting the serial port, the software establishes communication and 'Com OK' changes to green.

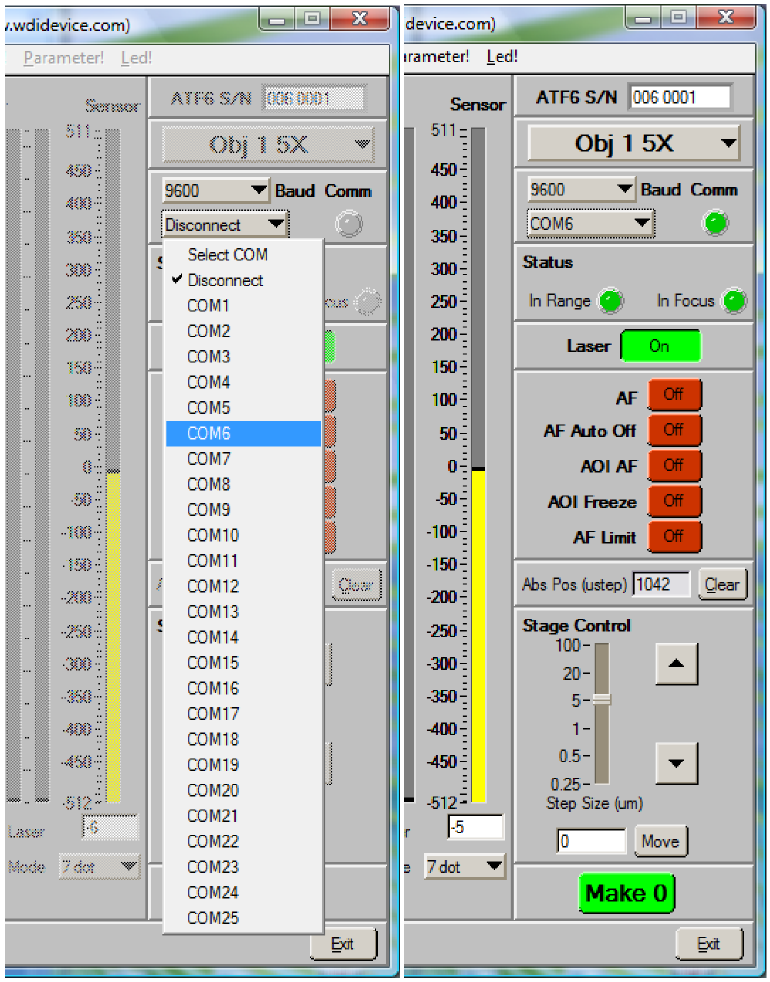


Figure 9-1 Select com port

9.2.2 Main window

The following functionality can be checked with the main window.

- output & laser
- motion
- AF (after loading correct parameters)

When the sensor is successfully connected to the software, the ATF Console Main window opens and looks similar to Figure 35, and the Baud rate Status indicator light turns green (Label 4), indicating a successful connection.

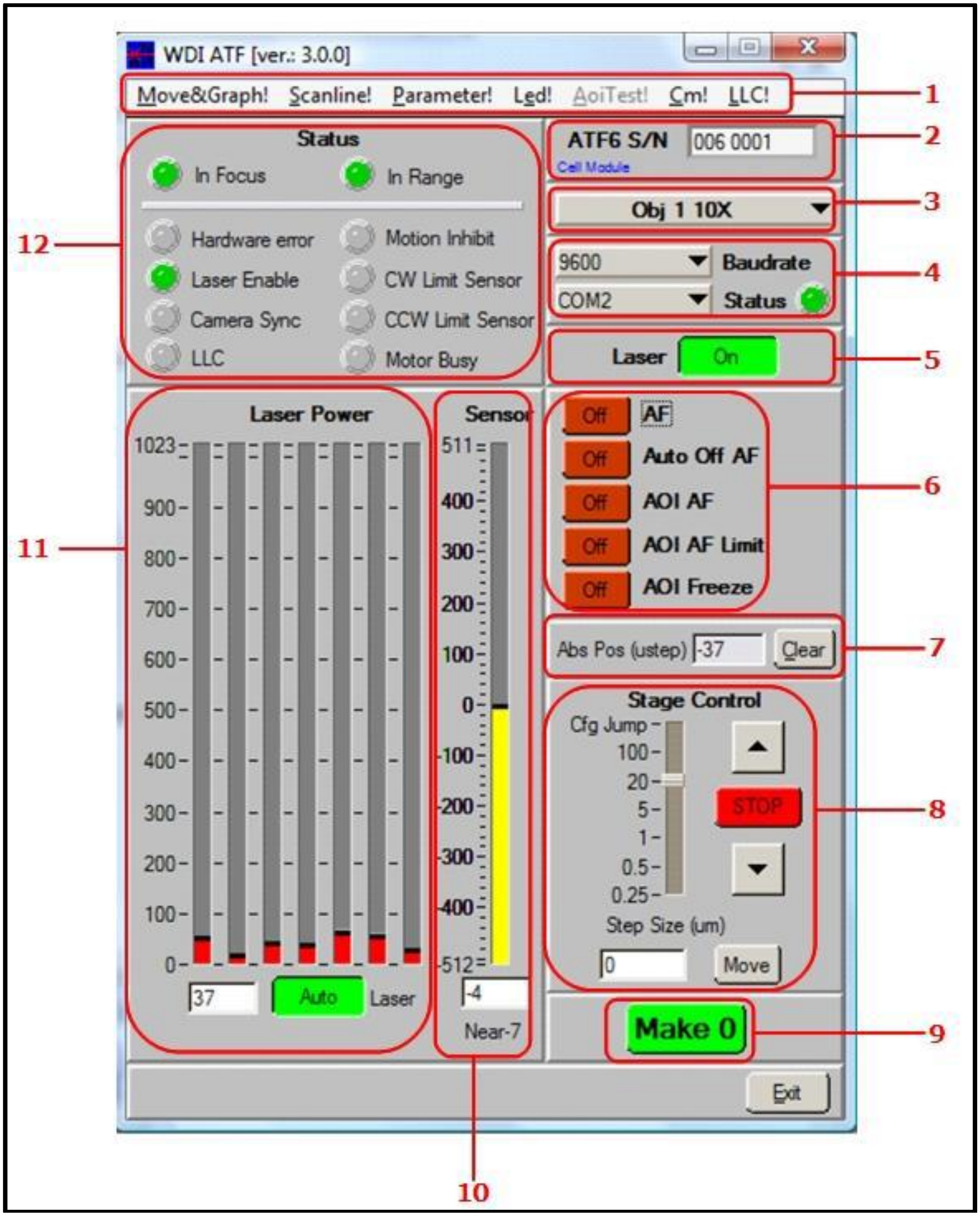


Figure 9-2 Main window description

ATF Console Main Window Labels

1. **ATF Console Menu Bar**
   - Navigate the software by choosing a menu item.
2. **ATF Sensor Serial Number**
   - Sensor model and serial number. Detects the current sensor. The blue font is the sensor model: Cell Module, SYS/AOI or Analog Output (SA).
3. **Objective Lens Selection**
   - Displays a list of all objective lenses. To select an objective lens, click the drop-down arrow.
4. **Serial Port Setup**
   - When the sensor is turned on, the default baud is 9600. You can select a faster baud by clicking the Baud rate drop-down arrow. Closing the ATF Console software or disconnecting the serial port (by using the same serial port control) resets the baud to the default of 9600.
   - Selecting the appropriate COM port establishes connection between the sensor and software, the **Status** light turns green, and several dimmed controls are available.
5. **Laser ON/OFF**
   - Turns the laser light on or off.
6. **Autofocus Modes**

   There are two autofocus modes available when all configuration parameters have been verified and adjusted in the Parameter Window.
   - **AF**—when the sensor is within Capture Range, clicking AF causes the sensor to focus on the target. The Sensor position indicator (Label 10) settles near 0, within the In-focus range as indicated by the Parameter Window, and the laser light remains on. The AF mode is optimized for stationary targets.
   - Auto Off AF—description is beyond the scope of this manual. For further information, see the *ATF5, ATF6 Console Software Reference Manual*.
   - Auto Off AF—description is beyond the scope of this manual. For further information, see the *ATF5, ATF6 Console Software Reference Manual*.
   - AOI AF—description is beyond the scope of this manual. For further information, see the *ATF5, ATF6 Console Software Reference Manual*.
   - AOI AF Limit—description is beyond the scope of this manual. For further information, see the *ATF5, ATF6 Console Software Reference Manual*.
   - AOI Freeze—description is beyond the scope of this manual. For further information, see the *ATF5, ATF6 Console Software Reference Manual*.
   - ATF Sensor User's Guide 1.3 34

7. **Abs Pos**
   - Absolute Position. Displays the sum of all motion steps performed since turning on the sensor, and then relates them to the Z stage position.
   - **To reset the text box to zero**
   - □□Click **Clear.**

8. **Stage Control**
   - Manually moves the Z stage by the number of micrometers indicated by the slider (set to 20 in label 8).
   - **To specify a positive or negative micrometer Z stage movement**
   - Type a value in the text box, and then click
   - **Move**.

   - **To halt the current motion**
   - Click **Stop**.

9. **Make0**
   - When you click **Make0**, the sensor records the laser spot(s) or line positions. The recording takes a few seconds. When complete, the sensor output value (yellow bar graph in the ATF Console Main window) is close to or equal to zero. When autofocus is enabled, the sensor tries to move to the Z position that best matches the recorded Make0 position.

   - **Important note**—successful and accurate measurements during the Make0 procedure is crucial for optimal sensor performance.

   - **Make0 is successful when:**
     - When all the laser spots, or the entire laser line (ATF6) is on a uniform material.
     - □Sensor output indicator (yellow bar graph in the ATF Console Main window) is close to or equal to zero and is not rapidly changing (screen shot to the right).
     - □Laser power for all spots (6 or 3) appears roughly as an "upward smile" shape. (The outer spots require higher laser power values while the central spots require lower laser power values). If one or more power values is significantly higher than the rest, Make0 has failed.
     - ATF Sensor User's Guide 1.3

     - All scanline peaks are clearly visible and clean (Figure 36). If one or more appear significantly smaller, wider, or noisier, Make0 has failed see Figure 37.

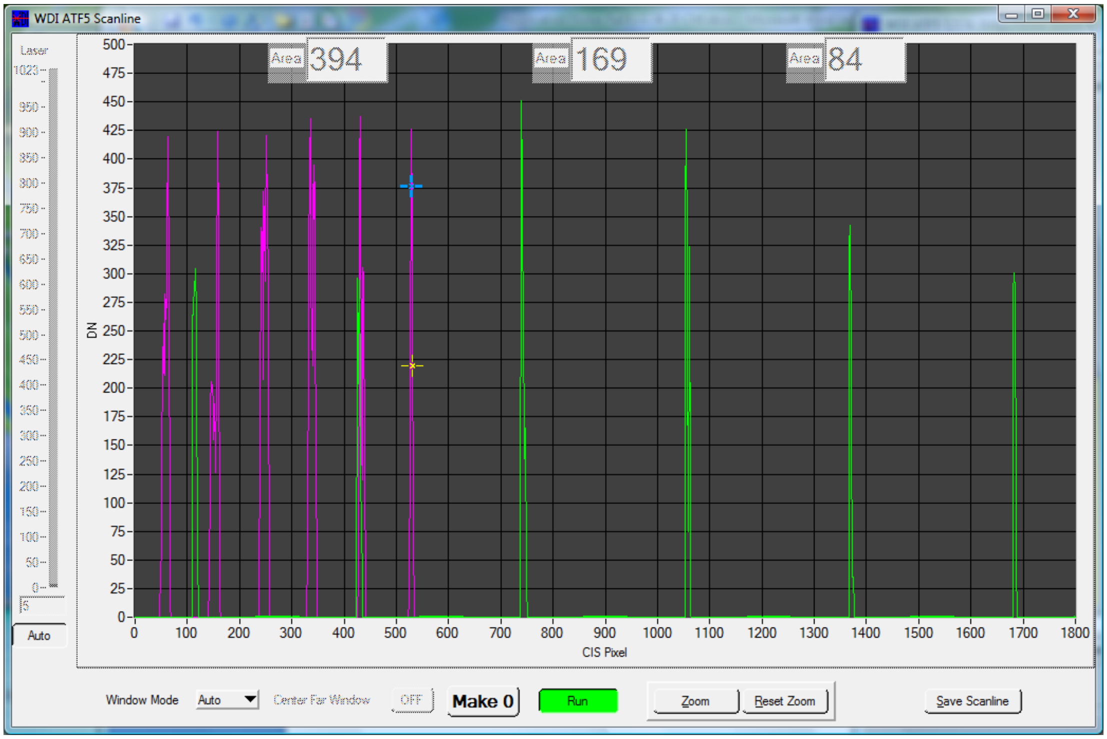


Figure 36 Clear, visible, and clean scanlines indicate successful Make0

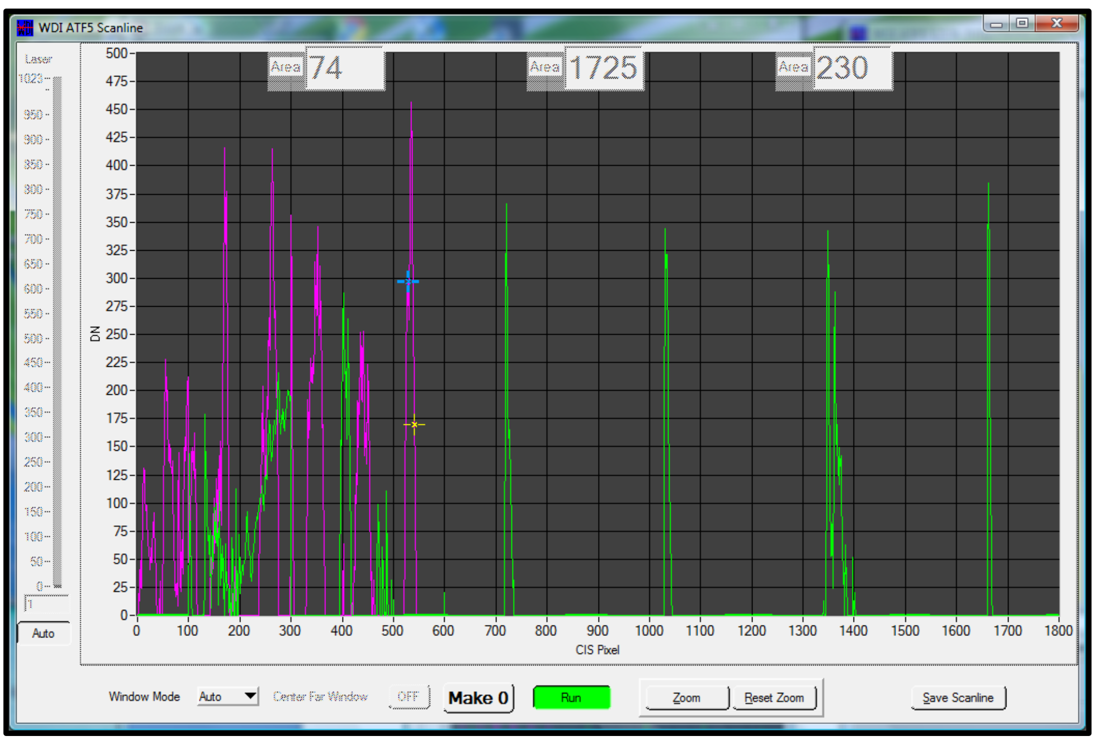


Figure 37 Two wide and noisy scanlines indicate unsuccessful Make0

When Make0 appears successful, but the outer laser power values are very high or saturated

- On the Parameter window, Surface Recognition area, Proc Opt, select **No Outliers Center Peak**.

(The Proc Opt parameter forces the sensor to only use the three center spots with higher power.)

Important Note:
Make0 only affects the currently selected objective lens and must be performed for each objective lens. Autofocus functions must not be attempted before Make0 is successfully performed.

10. **Sensor**

Sensor position bar graph representing sensor output, expressed in Digital Units (DU), which are arbitrary values ranging from -512 through +511 DU. When the sensor achieves focus, the sensor output conforms to the In-focus range parameter specified in the Parameter Window. (For more information about the In-focus range, see Chapter 11.1, Parameter Window Labels.)

Example—if the In-focus Range parameter is set to 10, the target is in focus with a sensor output range from -10 through +10 DU.

11. **Laser Power**

The seven red power indicator bars (Label 11) represent the laser power required for sensor operation. Depending upon the sensor mode and type, all or only some laser power indicator bars are active, that is, all or part(s) of the laser beam reflection is taken in to account when the sensor position is evaluated.

To maintain the signal level within a range that permits accurate sensor position measurements, the sensor regulates the laser power with every image acquisition.

The signal level depends on the following:

- Distance from focus
- Target surface reflectivity
- System calibration

The text box below the laser indicator bars represents the central indicator bar's digital value (set to 37 DU in label 11). The laser power measurement is expressed in DU, which are arbitrary values ranging from 0 through 1023 DU.

When one or more laser power indicators bars are higher than the rest, one or more laser spots or line segments are lost. The sensor compensates by increasing laser power.

Laser spot or line segment loss is often caused by:

- Non-reflective surfaces
- Laser beam being blocked inside the microscope or objective lens

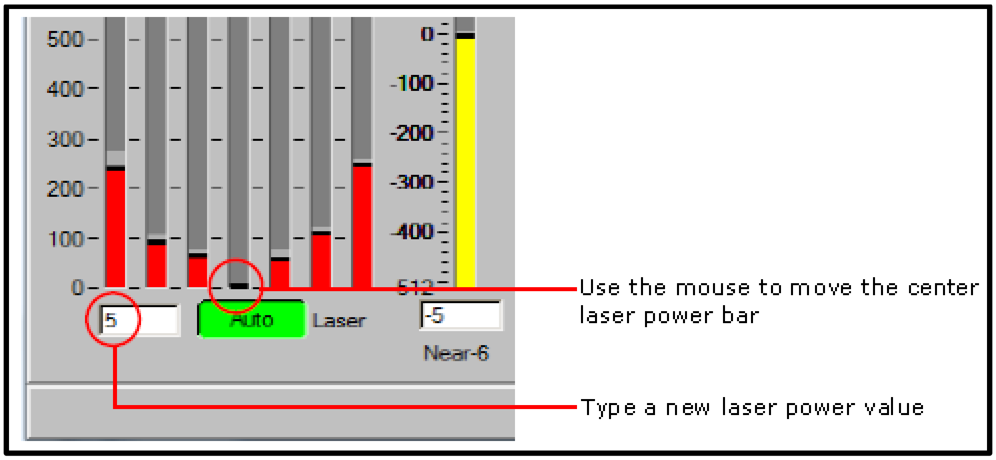
For system calibration and maintenance, the laser power can be adjusted manually by clicking **Auto**.

To manually adjust the laser power

1. Click **Auto**. The control changes to **Manual**.
2. Type a new laser power value in the text box (set to 5 in screen shot).

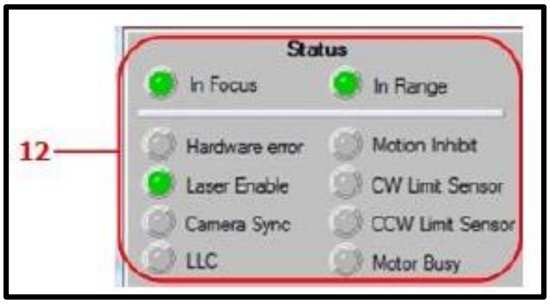
– or –

Use the mouse to move the center laser power bar.
Type a new laser power value
Use the mouse to move the center laser power bar.



12. Status

The Status part contains several LED indicators:



- **In Focus**—when green the sensor output is within the range set in the Parameter Window, **In-focus** range.

- **In Range**—the sensor is operating within the Capture Range and there is adequate reflected light reaching the sensor for it to detect the target.

- **Hardware error**—when red, indicates a hardware problem.

- **Motion Inhibit**—when yellow, indicates external digital input is preventing stage motion.

- **Laser Enable**—when green, indicates the laser is ON.

- **CW and CCW Limit Sensor**—Clockwise or Counter Clockwise Limit Sensor. When red, indicates that Z stage motion is stopped by a limit switch. Z stage movement is possible, but only in the reverse direction.

- **Camera Sync**—when green, sync digital input is asserted. (For more information about Camera Sync, see Chapter 12, SYNC.)

- **LLC**—Linear Lens Changer. The LED colors represent the following:
  - Grey—LLC is not detected.
  - Green—LLC is detected
  - Red—LLC is detected, but there is an error.

- **Motor Busy**—the Z stage is moving.

9.2.3 Move & Graph

Measuring outputs in steps provides vital information; linearity, linear range, capture range, and slope of the sensor coupled with an objective lens.

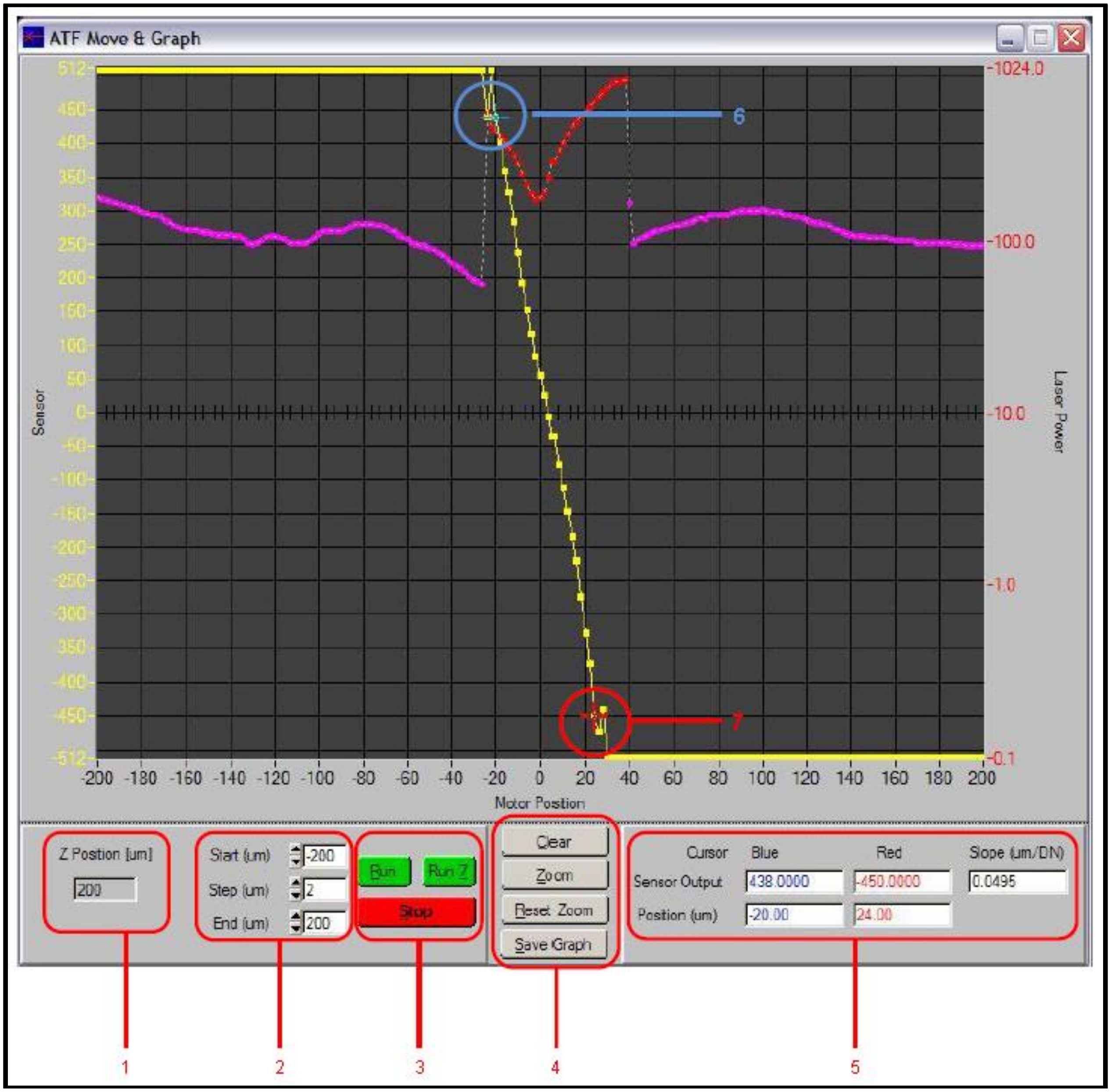


Figure 9-3 WDI Test Move & Graph window description

The following label descriptions pertain to Figure 9-3.

1. Current Position

Displays the current Z position (in μm), when running the Move&Graph plot.

2. Start, Step, End

Three values that define the Move&Graph plot:

- **Start**—the distance from the current position to the plot starting point (in μm). The default is -200 μm.

- **Step**—the distance between the two measurements. The default is 2 µm.
- **End**—the distance from the current position to the plotting end point (in µm). The default value is 200 µm.

3. Run, Run 7, Stop

- **Run**—starts the Move&Graph plot. The yellow color plot represents the Sensor Output, that is, the distance to focus position. The red color plot (Near Mode) and magenta (Far Mode) color plot represents the Average Laser Power values for each measurement position.
- **Run 7**—starts the Move&Graph plot for each laser spot or line segment. The green plots represent each laser spot or line segment positions, and the red (Near mode) and magenta (Far mode) color plot represents the Average Laser Power values for each measurement position. (For more information about Run 7, refer to the *ATF5, ATF6 Console Software Reference Manual*.)
- **Stop**—stops the Move&Graph plot.

4. Clear, Zoom, Reset Zoom, Save Graph

- **Clear**—clears the existing plot.
- **Zoom**—zooms to the area between the two cursors.
- **Reset Zoom**—zooms out to full view.
- **Save Graph**—saves the graph.

5. Sensor Output Slope Parameter Calculation Text Boxes

The text boxes with blue and red digits represent the blue cursor position (Label 6), and the red cursor position (Label 7) on the Sensor Output versus Position plot in the Move&Graph window.

To calculate the Slope parameter

1. Place the two cursors on the plot line's most linear part (middle section). The Slope parameter is automatically calculated and displayed in the **Slope (µm/DN)** text box.
2. Copy the number from the **Slope** text box in to the **Slope** text box in the Parameter window

9.2.4 Scanline

The ATF6 is well suited for high-speed autofocusing. On a very busy patterned surface, such as a semi-conductor or other rough surface. The ATF6 single laser line is made from seven segments that supply enough redundant information for the sensor to calculate the distance and direction to focus. When the target is out of focus the line expands to a rectangle.

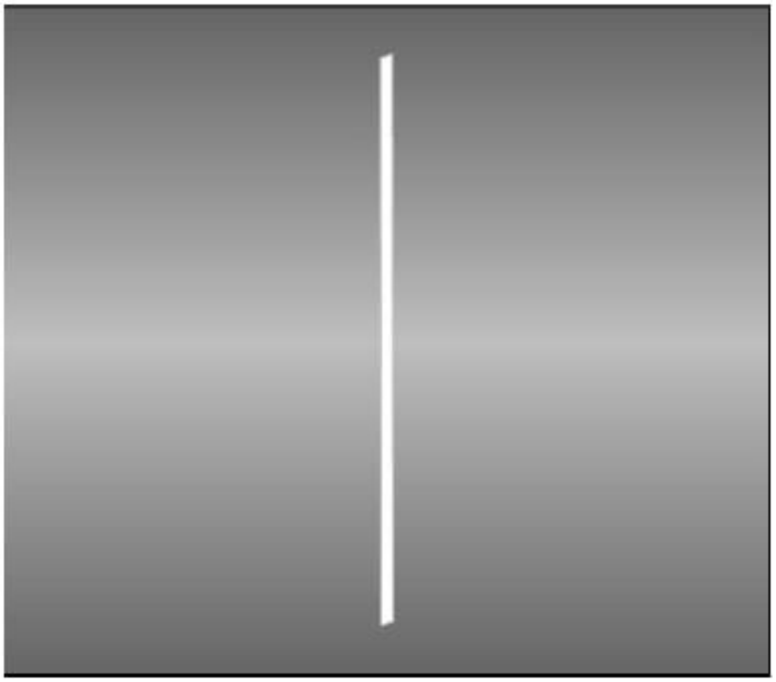


Figure 9-4 ATF6 camera image in focus (narrow line)

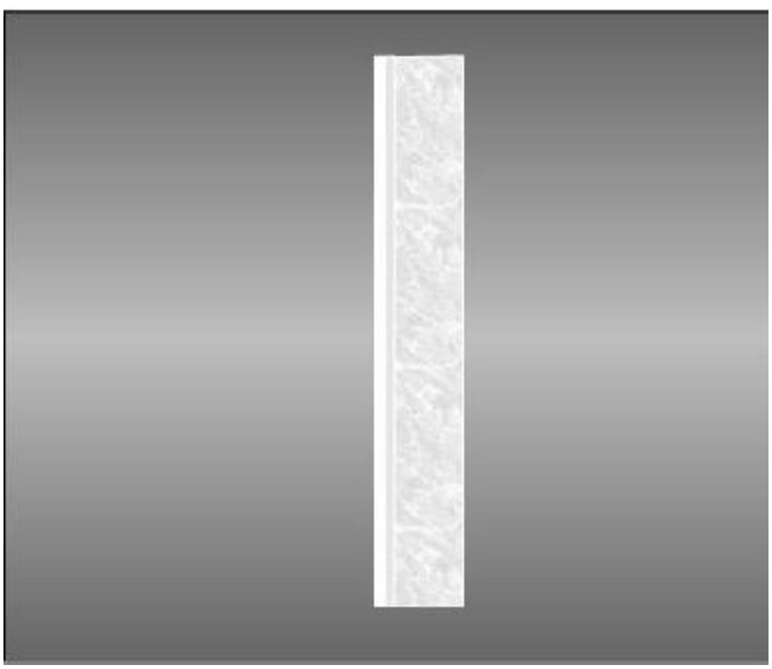


Figure 9-5 ATF6 camera image above focus (narrow line expands to a rectangle)

- The ATF6 forms seven windows, which produce seven distinct line segments, horizontal and vertical pixel summation provides a mathematical model of distance and direction to focus.

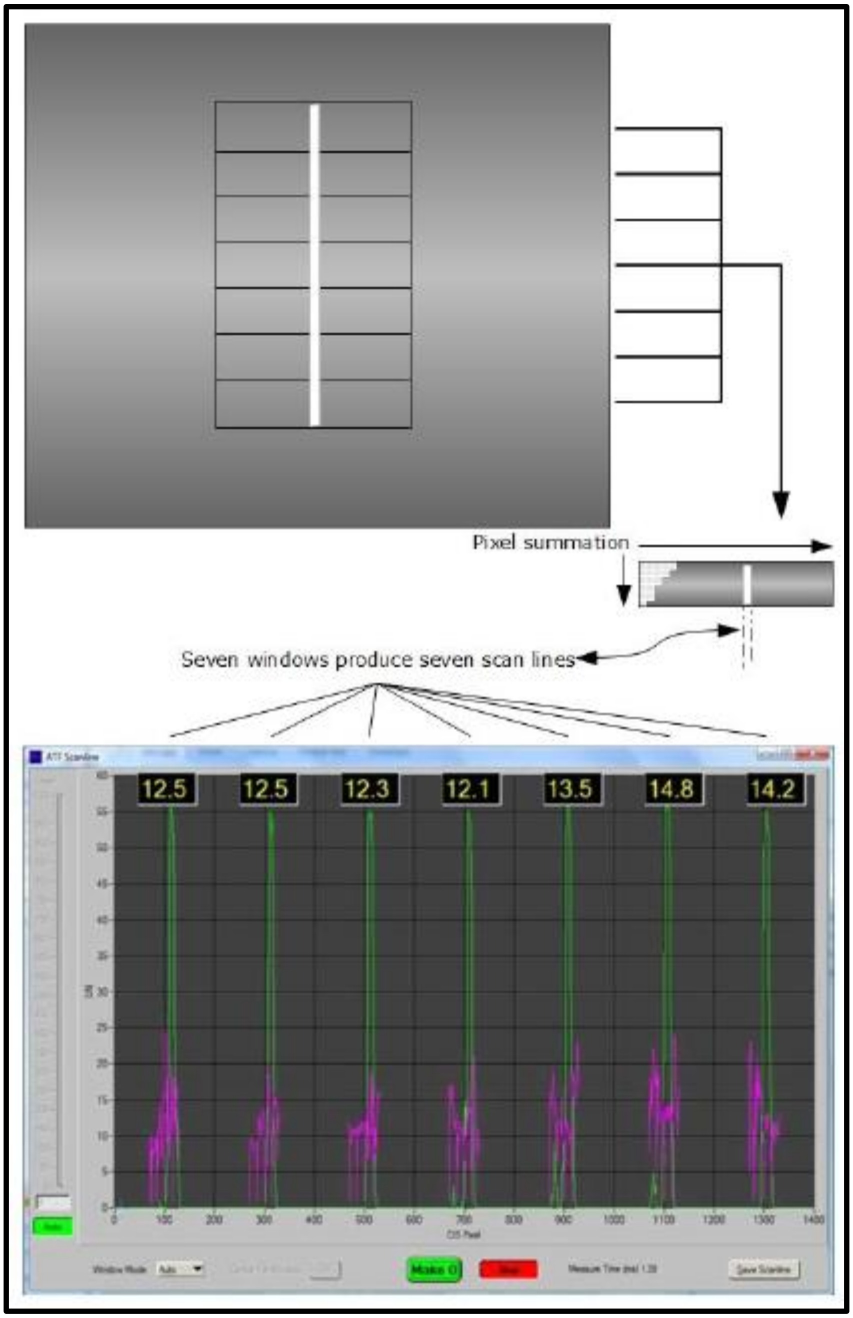


Figure 9-6 Seven scanlines produced from the ATF6

- The scanline is filtered data from the area imaging sensor and is helpful only on setup and diagnosing mysterious problem and normally not used.

- In the window, laser power and auto/manual control is reparative from the main window and the zoom and save works similarly as in the move & graph window.

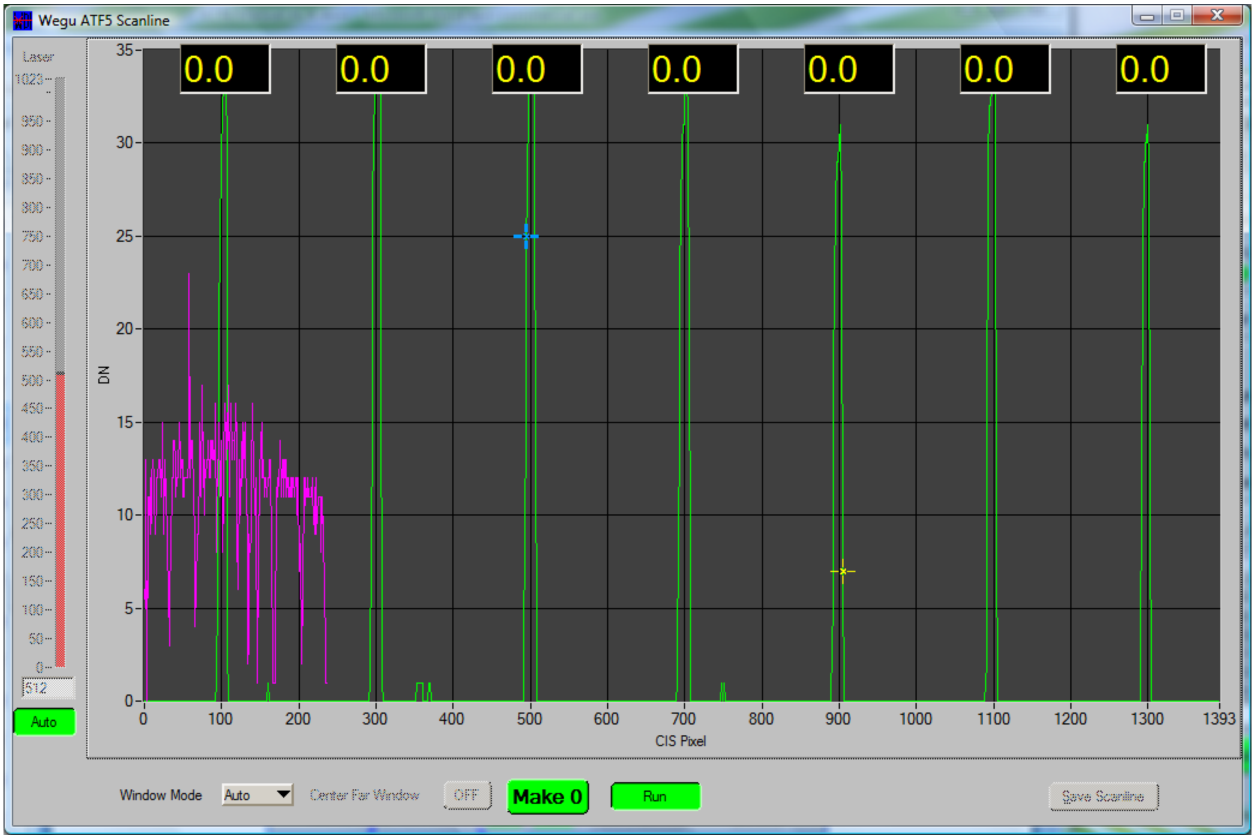


Figure 9-4 Scan-line Window description

9.2.5 Parameter

A sample Parameter window is shown in Figure 9-5. There is several text boxes that can be modified however, many are pre-set by WDI. The effect from a modified parameter is immediate and is lost when the sensor is reset or power cycled. When the performance is acceptable with the currently set parameters (even after resetting or a power cycling), click Save to Sensor. If the sensor is reset or turned on, the saved laser parameters are loaded.

80 Gough Rd. Unit 1 • Markham, On, L3R 6E8 • Canada
Phone +1 (905) 415-2734 • www.wdidevice.com

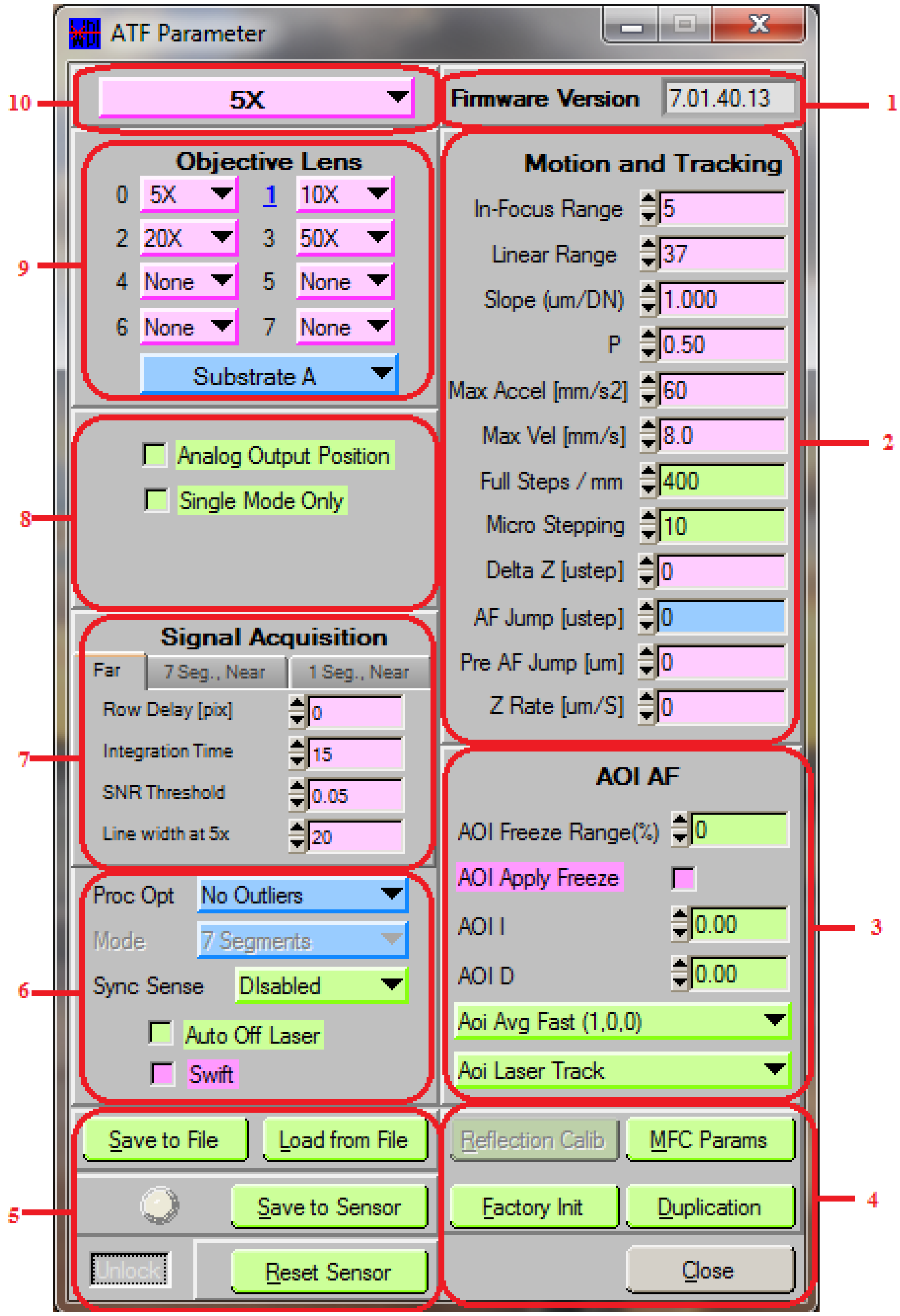


Figure 9-5 Parameter window

The following label descriptions pertain to Figure 9-5.

1 Firmware Version

Displays the current sensor firmware version.

2 Motions and Tracking

A group of parameters that affect Z stage motion. The **P** and **Max Accel** text boxes help reduce the time required for AF and AOI AF functions.

Important note—setting the **P** and **Max Accel** parameters too high can cause oscillation or vibration!

- **In-focus range**—expressed in DU (sensor output). The default values for this parameter are matched to the Mitutoyo objective lenses, and the user is generally advised against modifying this parameter. When other manufacturers' objective lenses are used, this parameter may need modification since it is NA dependent and since the DOF is NA dependent.

- **Linear range**—expressed in DU (sensor output). The range in which the sensor operates in Linear Mode. The default values are set to represent average sensor performance

- **Slope**—a conversion factor that relates Z stage distance (in µm) to sensor position. The Slope parameter is measured by using the Move&Graph window. (For more information about Slope, see Chapter 13.1, Slope Parameter.)

- **P**—Proportional gain coefficient. You are advised against modifying this parameter. The factory default value is optimized for speed versus stability. Decreasing **P** makes focusing more stable, but less responsive. Increasing **P** speeds up focusing, but can make focusing less stable, by overshooting.

- **Max Accel**—Maximum Acceleration and Deceleration rate. The sensor can request maximum acceleration when scheduling Z stage movement. The **Max Accel** value is generally set at 70%, or lower than the value that causes occasional Z stage slippage. Increasing this value increases the superstructure vibration and may increase the settling time and autofocusing time.

- **Max Vel**—Maximum Velocity. The sensor can request maximum velocity when scheduling Z stage movement. The **Max Vel** value is generally set at 70%, or lower than the value that causes occasional Z stage slippage. During autofocusing the maximum velocity is seldom reached. Increasing this value does not affect the focusing time.
    - **Full steps**—the number of full steps required for the stepper motor to move the Z stage by 1 millimeter.
    - **Micro stepping**—the number of micro-steps the stepper motor takes for each full step. When a WDI stepper motor is used (models MFC or MFZ) the available micro-steps are: 2, 4, 8, 16, and 32; where 16 is the default value. If you supply the stepper motor, consult the hardware specifications, and then type the number in the text box.
    - **Example**
        - Motor→200 full step/revolution
        - Linear actuator→0.5 mm/revolution

- Therefore, **Full steps/mm**=100

3 AOI AF

These parameters optimize AOI AF continuous tracking mode. (For more information about All Substrates, refer to the *ATF5, ATF6 Console Software Reference Manual*.)

4 Control Group

- Reflection Calibration— description is beyond the scope of this manual. For further information; see the *ATF5, ATF6 Console Software Reference Manual*.

- MFC Parameters—description is beyond the scope of this manual. For further information, see the *ATF5, ATF6 Console Software Reference Manual*.

- **Factory Init**—initializes the sensor to its default condition and overwrites all user parameters. The user must re-define all parameters and perform Make0 on all objective lenses.

5 File Operations

- **Save to File**—saves all parameters from the sensor to an **.atf** text file. Works at 9600 baud only.
- **Load from File**—loads parameters from an **.atf** text file to the sensor. Works at 9600 baud only. Users can copy (duplicate) the settings from one sensor to another. After loading the new settings, the user must perform Make0 on all objective lenses.
- **Save to Sensor**—preserves current parameter settings to the sensor's non-volatile memory. When the sensor is turned on, the saved parameters are loaded.

6 Proc Opt

- **Mode** – This describes the mode in which the laser is operating and how many line segments are being analyzed.
- **Sync Sense**—enables or disables the sync digital input.
- Mode – This describes the mode in which the laser is operating and how many line segments are being analyzed.
- **Auto Off Laser** – This automatically switches the laser off when autofocus is not active. It is set to OFF by default.
- **Swift** – This activates the SWIFT Tracking System. It is set to OFF by default.

7 Signal Acquisition

- Row Delay—description is beyond the scope of this manual. For further information, see the *ATF5, ATF6 Console Software Reference Manual*.
- Int. Time—description is beyond the scope of this manual. For further information, see the *ATF5, ATF6 Console Software Reference Manual*.
- S/N Thr—description is beyond the scope of this manual. For further information, see the *ATF5, ATF6 Console Software Reference Manual*.

8 Other parameters

These parameters control the behavior of the Sensor's output.

9 Objective Lens

The Objective Lens part contains eight controls (numbered 0–7), to each of which an objective lens and its corresponding slot is assigned. Label 8 indicates that the current system has three objective lenses attached (numbered 0–2), with five more available slots. Number 0 objective lens appears in blue, indicating it is selected.
When objective lenses are mapped to slots 0 through 7, several parameters is changed in the Parameter window. If no magnification value is associated with the objective lens, the default value is **None**. After changing the magnification, Make0 must be performed for each objective lens.

- **All Substrates**—you can select from five substrates. The default setting is All Substrates, which applies one Make0 setting to all substrates. A separate Make0 can be applied to the remaining four substrates. (For more information about All Substrates, refer to the *ATF5, ATF6 Console Software Reference Manual*.)

10 Objective Lens Selection

The Objective Lens Selection control in use in the ATF Console Main window.

Chapter 10

APPS QUICK NOTES

10.1. CENTERING PEAK AT SCANLINE WINDOW

ATF6 has 2 adjusters A, B at the bottom of the chassis. Please refer to Figure 10-1 below. The Adjuster A shift signal (Red Square on above picture, smallest at focus larger at larger distance) basically sideways with respect of the ATF6 linear detector (blue), while Adjuster B shifts it along. Please note that there is an angle of about 30 degree and both adjusters induce some shifts of the signal that needs to be compensated with little iteration.

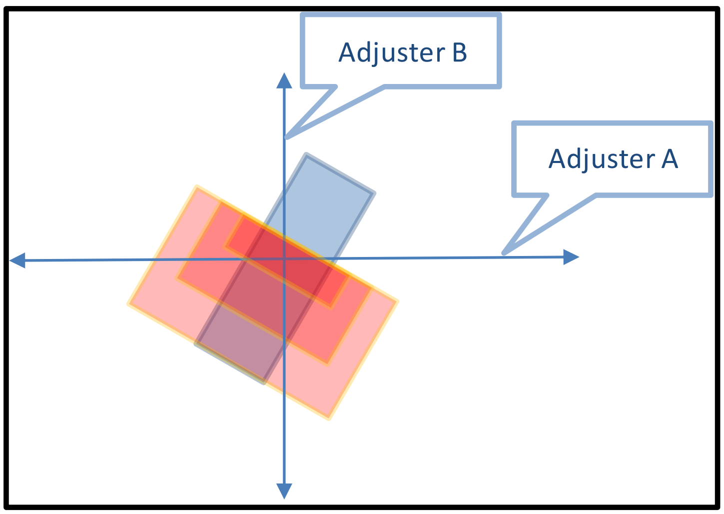


Figure 10-1 ATF Sensor Adjuster

Step procedure as follows:

1) Bring camera to best focus on un-patterned target with 5x or 10x (low mag lens)

2) Run SCANLINE, switch to far mode and select "Center Far Window"

3) Manipulate Adjuster B to bring signal to 0 (Main panel yellow Sensor bar)

4) Set Manual laser power and turn auto-scaling OFF

5) Turn Adjuster A both direction by about +-½ of full rotation. Observe peak height rising and falling. Find position of the maximum peak height.

6) Set Auto laser power mode and auto-scaling ON

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7) Is Sensor position at +-20? if not go to step 3). If yes go to step 8)

8) Turn off "center far mode", switch to auto mode

9) Make0

10) Save to sensor.

The above procedure will zigzag ever closer to the optimal position. It is important that adjuster A, more important of the two is manipulated last.

At the end of this procedure green peak will stand in the center pix position. The Adjuster A has to place signal at maximum height otherwise section of the line used by ATF7 is going to be unnecessarily reduced.

The 20x objective has a dynamic row delay specified at 10000. This means that under normal circumstances ATF6 is operating at 0.86ms. However if ATF6 is unable to get signal at that speed it is going to slow down acquisition in order to gain extra time to see weak signal. See the scanline "Measure Time" for current interrupt length of time. If in your system at 20x there is enough laser intensity ATF6 will operate at full speed. Run m&g and you will see the discontinuity in magenta laser power signal every time more row delay was needed.

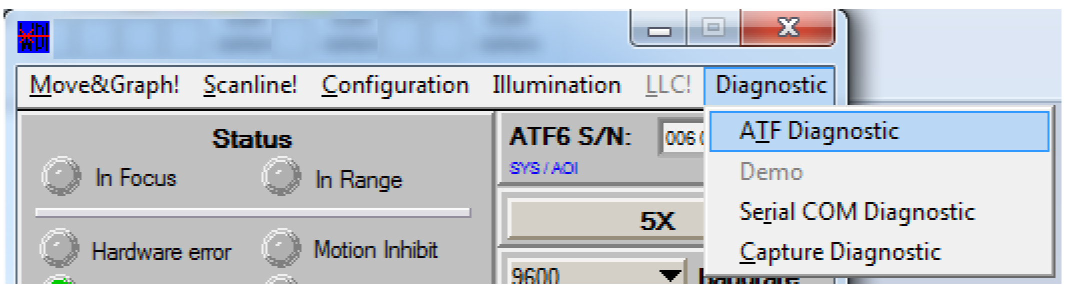
10.2. ATF SENSOR TROUBLESHOOTING GUIDE

How to use this guide

This guide should be used to pinpoint and solve specific issues. It is not meant as a replacement for the ATF User's Manual, which should be consulted thoroughly before using this guide.

To use this guide, first follow the Standard Troubleshooting Procedure, on Page 2. If this does not resolve your issues, identify your issue using the index on Page 4. Follow each Solution Step in order. After each Solution Step, check to see if your issue has been resolved. If it has not, move on to the next Solution Step.

If your issue is still unresolved after going through each Solution Step, please take screenshots of your issue (where possible) and run the ATF Diagnostic tool found in the Diagnostic menu in the ATF Console. The Diagnostic tool will generate a file with the extension *.diag*. Please send all screenshots and the *.diag* file, along with a detailed explanation of your issue, to the following email address: appsengineering@wdidevice.com. One of our engineers will contact you shortly.



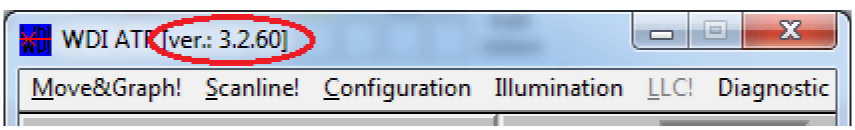
ATF Diagnostic Tool – Run this if all other solutions fail.

Standard Troubleshooting Procedure

Before attempting any of the solutions in this guide, please complete the following steps. If these do not rectify the issues with your sensor, consult the section of this guide covering your problem. If your problem persists, or is not covered in this guide, please contact WDI.

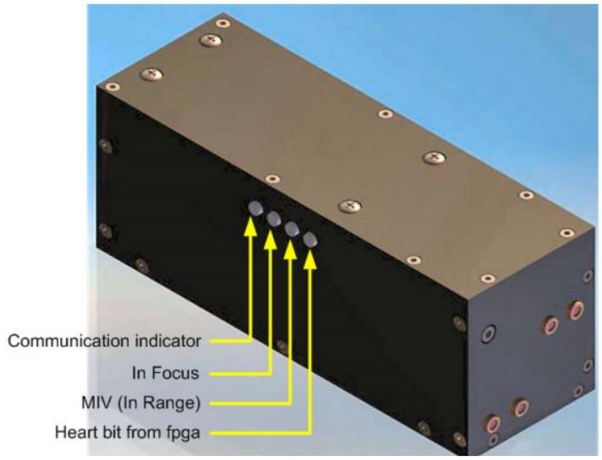
Step 1: Ensure that the sensor is correctly installed and aligned as demonstrated in the ATF User Manual. If the sensor is incorrectly aligned (for example, the laser is not entering the objective correctly, or the laser image is not being reflected into the center of the photodiode) the sensor's linear range, focussing ability or accuracy could be affected.

Step 2: Ensure that the system connected to the sensor has the correct ATF Console Software installed. Some sensors will not function optimally if paired with software versions older than the sensor itself, and communication issues can be a result of this mismatch. If your sensor is new, ensure that you have the latest build of WDI's ATF Software installed. If your sensor is older, ensure that the software is either the version the sensor shipped with or a newer version. If you are unsure of whether you have the latest Software update installed, please see WDI's website or contact us directly.



ATF Console Version Number

Step 3: Ensure that the Power LED on the Sensor is lit. If the sensor is receiving power but the Power LED is not lit, this means that the internal fuse has blown. The sensor will need to be returned to WDI for repair.



External Sensor LEDs

Step 4: Power cycle the sensor. Some issues can be fixed simply by rebooting the sensor completely.

Note: *If these steps to do not fix the issues with you sensor, please use the index on the following page to identify your problem and its solution.*

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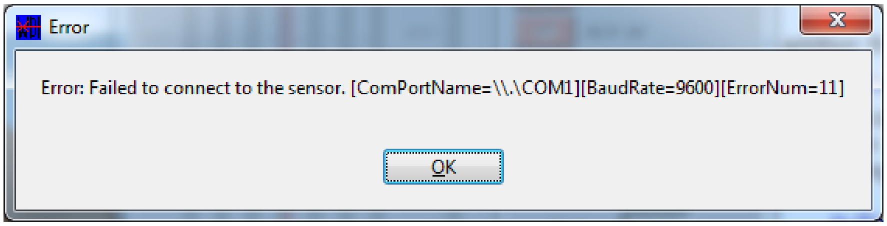
Issue 1 - ATF Sensor not connecting to sensor or not responding to commands



Error message indicating that ATF Console is unable to communicate with ATF Sensor

Solution Step 1A

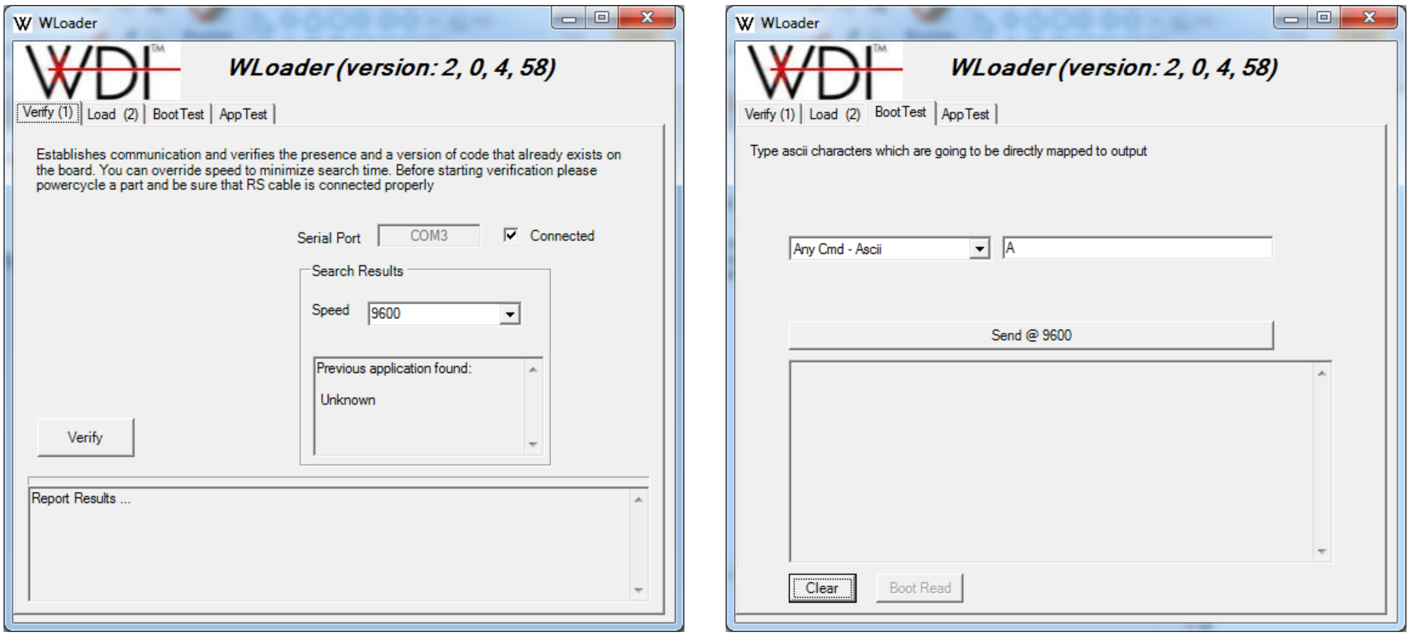
Provided that the sensor is receiving power (see Standard Troubleshooting Procedure, page 2), the most likely cause of communication issues is faulty cabling. If possible, replace the currently installed ATF sensor with a spare sensor. If the issue persists, the likely cause is faulty or broken cables. Replace all cables connecting the ATF and controller to one another and to the PC. Restart the sensor and attempt to connect again. Ensure that you have identified the correct Port to connect to.

Solution Step 1B (Not applicable for Low Power ATF4 Sensor)

If the sensor continues to be unresponsive, use a piece of paper (or an IR Card for sensors with a 785nm laser) to check that the ATF laser is functioning. This can be placed either directly in front of the ATF sensor's lens, or in front of the microscope's objective. If there is no visible light and the laser interlock is nonactive, the laser diode has malfunctioned. In this case, the sensor should be returned to WDI for repair. If there is a visible laser spot, but the sensor remains unresponsive, move to the next Solution Step.

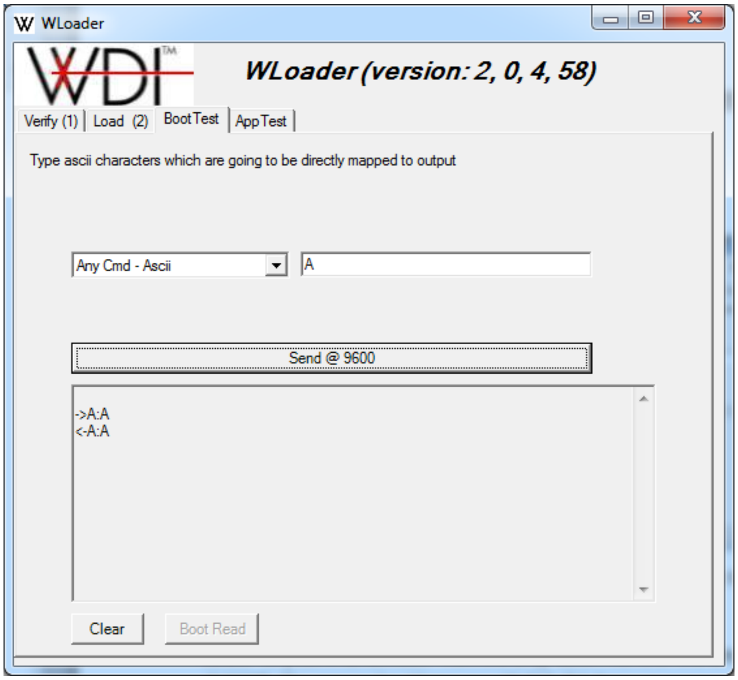
Solution Step 1C

Open the Wloader software. Connect to the sensor by typing the appropriate port name into the Serial Port control, then clicking the Connected check box. Select a Baudrate of 9600, and click on the BootTest tab.



Wloader Software on start-up (left) and Boot Test Tab (right)

Select "Any Commands ASCII" from the drop-down menu on the left hand side, type "A" and click "Send @ 9600". The sensor should answer with "A". If it does, your sensor is responding appropriately to commands and should be functioning normally. If you receive an "A" response, please move on to Solution Step 1D.



Wloader Software with "A" command sent and "A" response received.

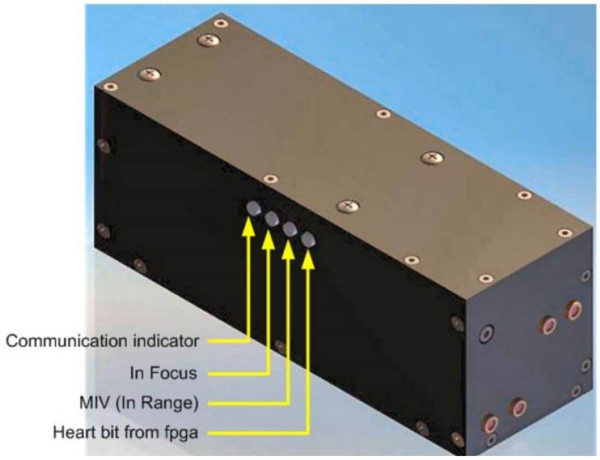
If you receive no response to the "A" command, your sensor is not receiving any commands, meaning that there is a fault either with the serial port or the cables being used. Please check these thoroughly.

If you receive a "K" response, this indicates that the sensor is incorrectly programmed and must be reprogrammed by WDI.

Solution Step 1D

After receiving an "A" in response to the "A" command, change the "A" in the control window to "Z" and press Send @ 9600 again. This will send a reset response to the sensor. If the sensor application is running, you should receive an "N" is response. If you receive this response, continue to Solution Step 1E.

If the sensor application is not running, the sensor will respond to the "Z" command by resetting. The external LEDs should blink and you will receive an "A" response. If this occurs, return to Solution Step 1C and repeat the process.

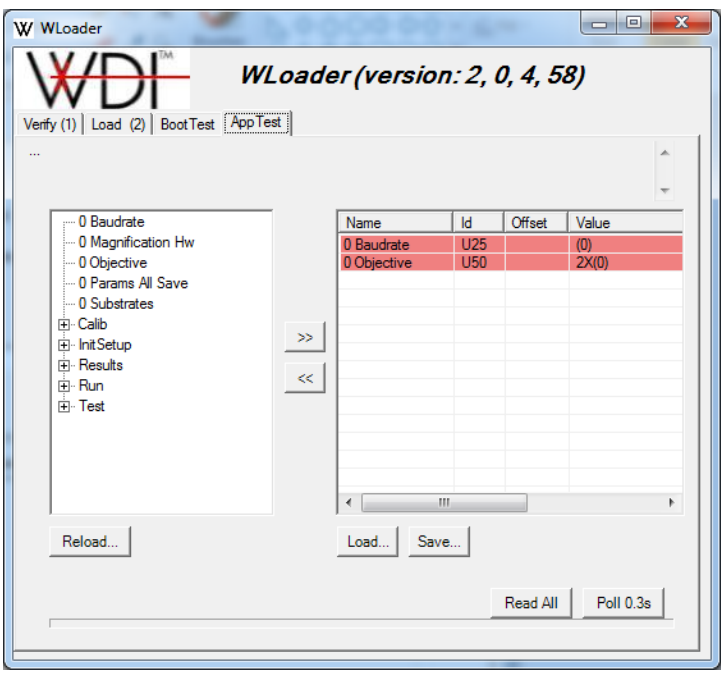


External Sensor LEDs

Solution Step 1E

Select the AppTest tab in the Wloader. Double-click on "0 Baud rate" and "0 Objective" in the left hand side list. Equivalent items will appear in the right hand side list. If these items appear highlighted in Red, then a sensor firmware mismatch has occurred and the sensor must be reprogrammed.

If they appear in the color salmon pink, communication is proceeding normally.



Wloader software with no communication issues.

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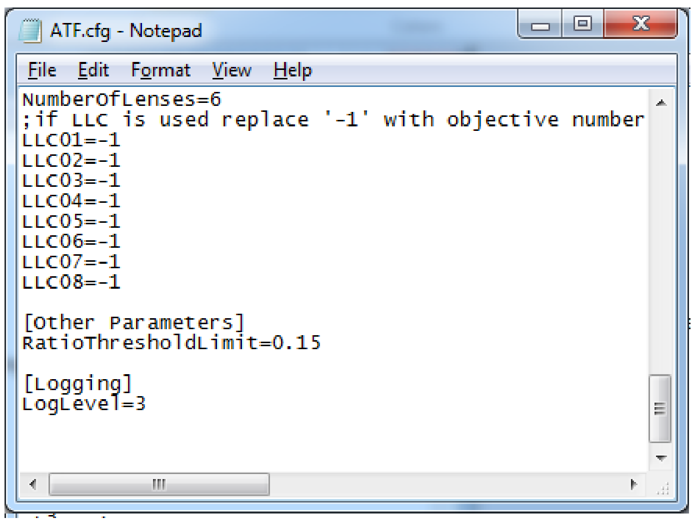
Solution Step 1F

Navigate to the folder in which the ATF Console software is installed, and locate the ATF.cfg file. Open it using any simple text editing software and scroll to the final parameter, which should be entitled “LogLevel”. Ensure that this parameter is set to 3 (file should read “LogLevel=3”). If LogLevel is not set to 3, set it to 3 and save & exit the file.

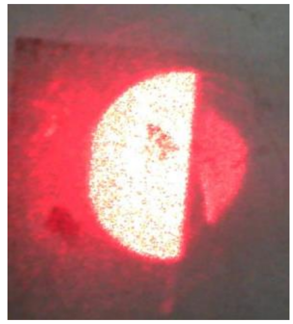
Open the ATF Console and attempt to connect to the ATF Console. If you are successful, attempt to replicate any communication issues you have experienced.

If any issues are still experienced, send the file ATF_Console.log (located in the same folder as ATF.cfg) to WDI for analysis, along with screenshots of the issue and the *.diag* file, as discussed in Standard Troubleshooting Procedure.



ATF.cfg file with LogLevel set to 3.

Issue 2- ATF laser dot is not a perfect half-circle, has some blurring or over spilling.

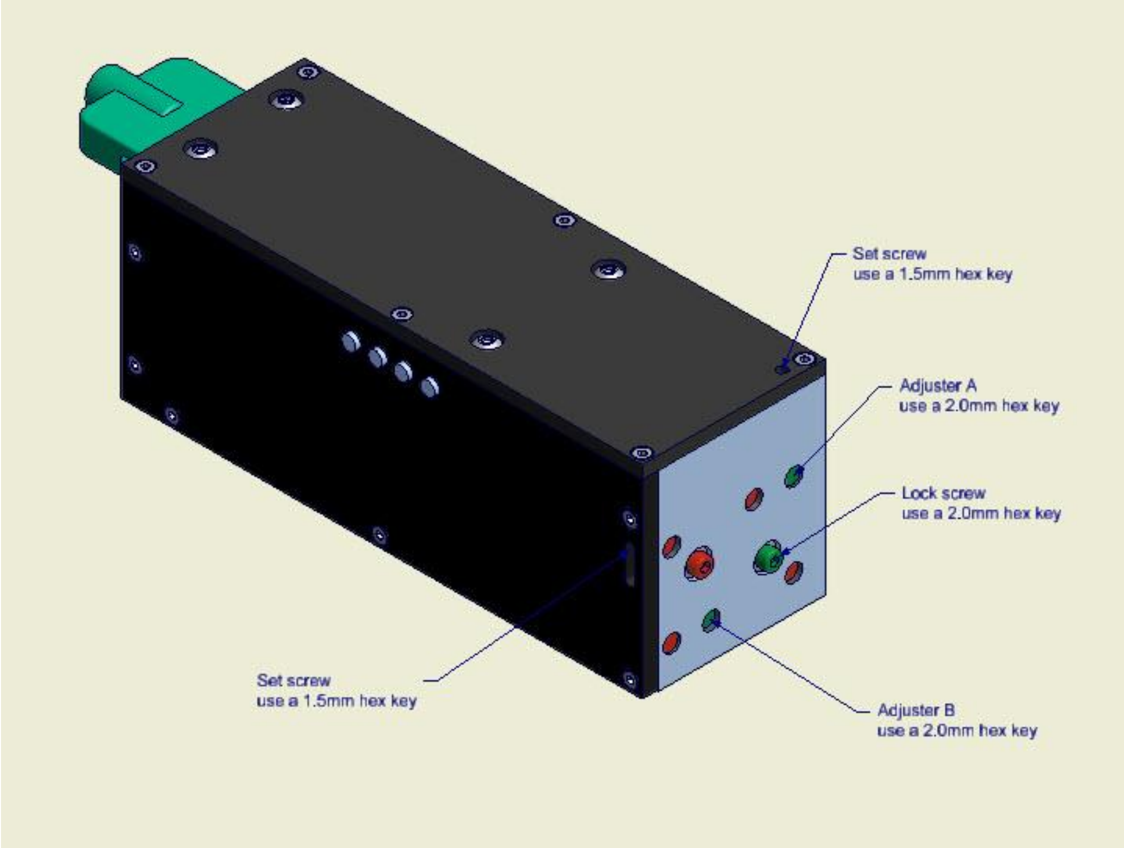


Example of over spilling laser dot.

Solution Step 2A

Check laser power using a 20X magnification objective lens, with the automatic laser power setting engaged. Values of 10-20 are expected. If the laser power is notably higher than this (more than ~25-30), the laser may be misaligned. Complete the following steps to re-align the sensor:

1) Bring sensor into focus
2) Rotate the Lock Screw counter clockwise by a **half turn**. This will unlock adjuster A. **Failing to unlock the adjuster before turning it will damage the adjuster.**
3) Turn adjuster A (see diagram) slightly while observing the laser power. Continue turning the adjuster slowly until a minimum in laser power is found. **NOTE: Adjuster A should never be turned by more than 1 full rotation as this can damage the sensor.**
4) Move the adjuster slowly to the left and right to establish a range over which the laser power remains at its lowest point. Move the adjuster to the middle point of this range.

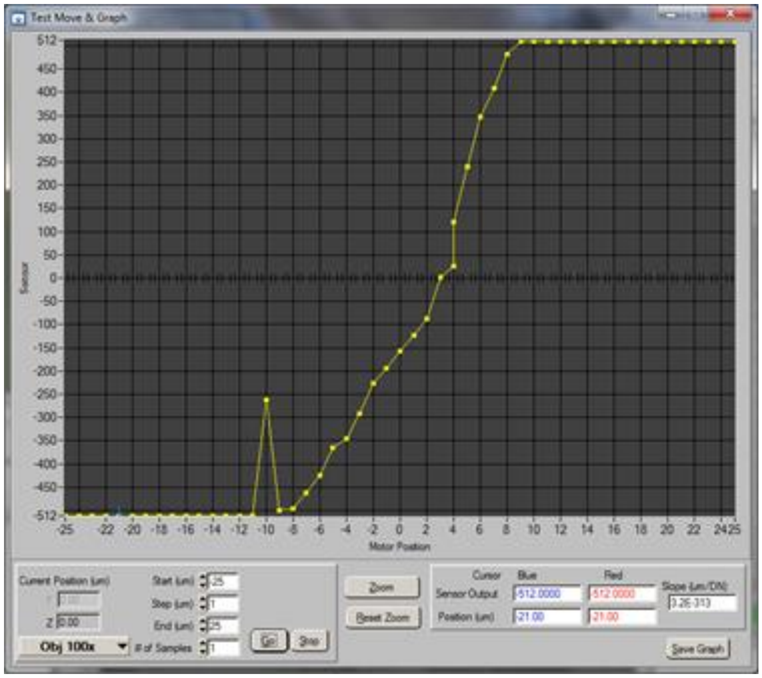


Screws and Adjusters. Adjuster A is labelled in red.

Solution Step 2B

One cause of this issue can be defective or dirty optical components. Ensure that the objective lens, beam splitter, and any other optical components between the sensor and the sample are clean and without faults. If the laser power is higher than expected (10-20 when using a 20X lens), it is likely that there is some obstruction preventing the laser light from reaching the photodiode. Switch out all components to ensure that the optical components are free from issues.

Issue 3 - ATF is not behaving linearly within linear range.



Example of nonlinearity in linear range of sensor.

Solution Step 3A

One cause of this issue can be defective or dirty optical components. Ensure that the objective lens, beam splitter, and any other optical components between the sensor and the sample are clean and without faults. If the laser power is higher than expected (10-20 when using a 20X lens), it is likely that there is some obstruction preventing the laser light from reaching the photodiode. Switch out all components to ensure that the optical components are free from issues.

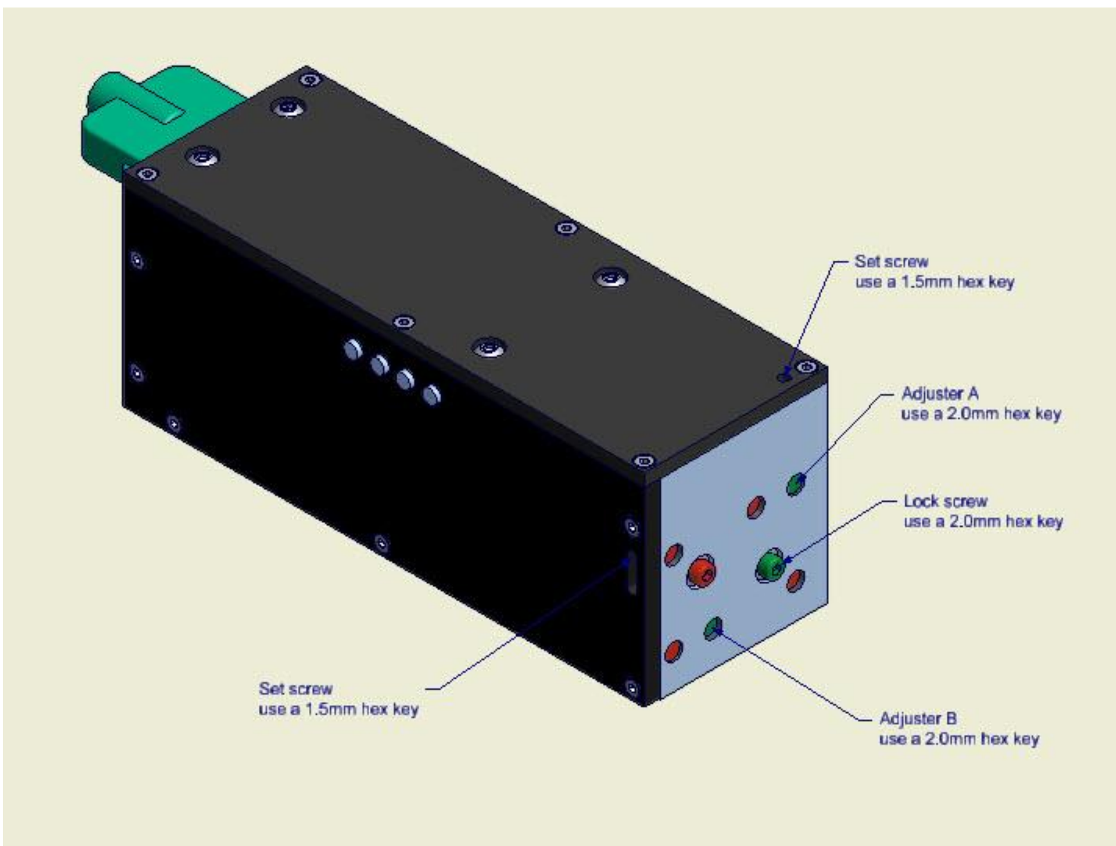
Solution Step 3B

The linear range of the sensor is affected by the sensor's vertical alignment. Attempt a small adjustment (~0.5mm) of the sensor's vertical position and run the Move & Graph. If the linearity improves, continue to adjust the sensor's vertical position in the same direction in small increments, running Move & Graph after each step. Continue this process until the sensor's response within the linear range is linear.

Solution Step 3C

This could also be caused by the sensor's sideways alignment. Complete the following steps to re-align the sensor:

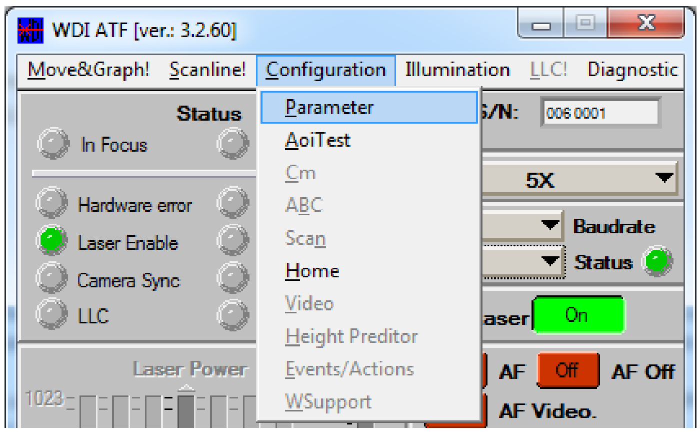
1) Bring sensor into focus
2) Rotate the Lock Screw counter clockwise by a **half turn**. This will unlock adjuster A. **Failing to unlock the adjuster before turning it will damage the adjuster.**
3) Turn adjuster A (see diagram) slightly while observing the laser power. Continue turning the adjuster slowly until a minimum in laser power is found. **NOTE: Adjuster A should never be turned by more than 1 full rotation as this can damage the sensor.**
4) Move the adjuster slowly to the left and right to establish a range over which the laser power remains at its lowest point. Move the adjuster to the middle point of this range.



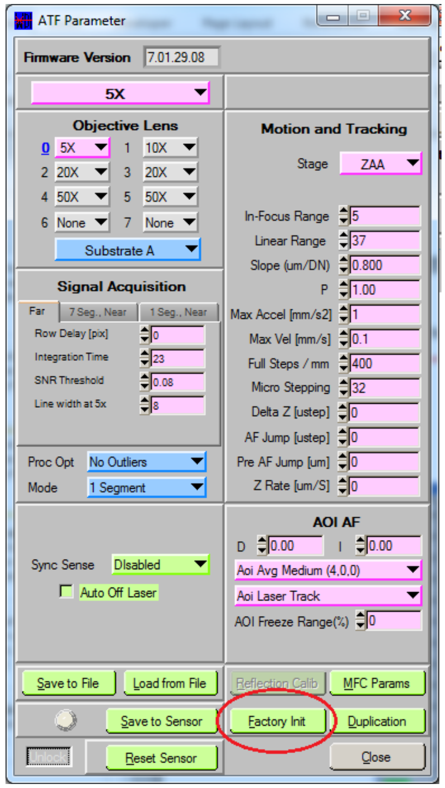
Screws and Adjusters. Adjuster A is labelled in red.

Solution Step 3D

This issue could simply be a case of incorrect parameters being entered into the ATF console. Ensure that the correct objective lens is selected in the ATF Console Software. Next, open the Parameter pop-up window from the configuration menu. Click the “Factory Init” button in the bottom of the Parameter window to reset all parameters to their default values. **Note, any changes that have been made to the parameters, including any parameter values specific to your set-up, will be lost.**



Accessing the Parameter pop-up window.



The Factory Init. button.

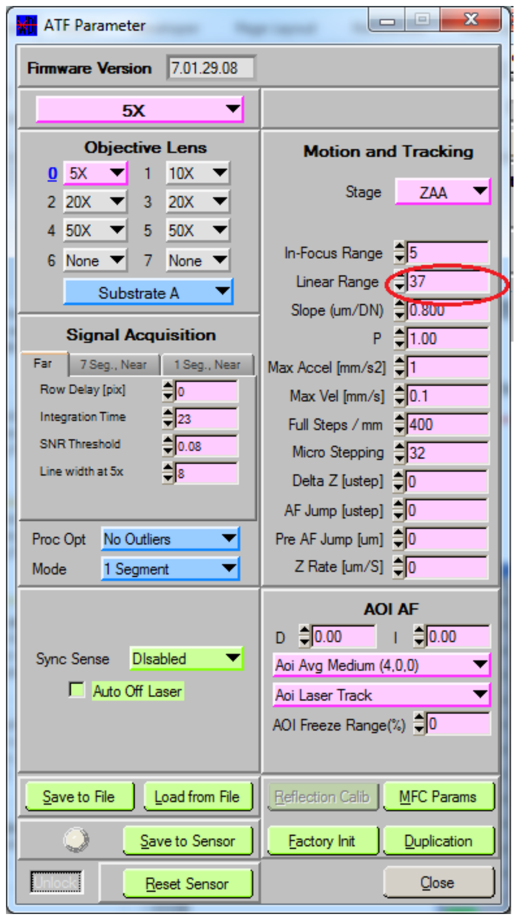
Solution Step 3E

It is also possible that reduced linearity can be due to the sample being used. Specific samples and conditions can cause the ATF4 Sensor's linear range to be severely reduced, particularly if there is metallization present in the sample. Measure the linear range using the same set-up, but with a different sample. If this rectifies the problem, consult WDI on how to adjust the ATF sensor's parameters to compensate for your desired sample.

Issue 4 – The linear range of the sensor is too small

Solution Step 4A

The linear range of the sensor can be increased in the Parameters pop-up window, accessed via the Configurations menu. However, increasing linear range can impact the sensor's linearity. If this occurs, please see Problem 3. Increasing the linear range will result in a different sensor response slope, so after taking this step, the slope should be re-measured and re-entered into the Parameters window.



The Linear Range parameter.

Issue 5 – The sensor's output is unstable/ is switching quickly over a large range of values

Solution Step 5A

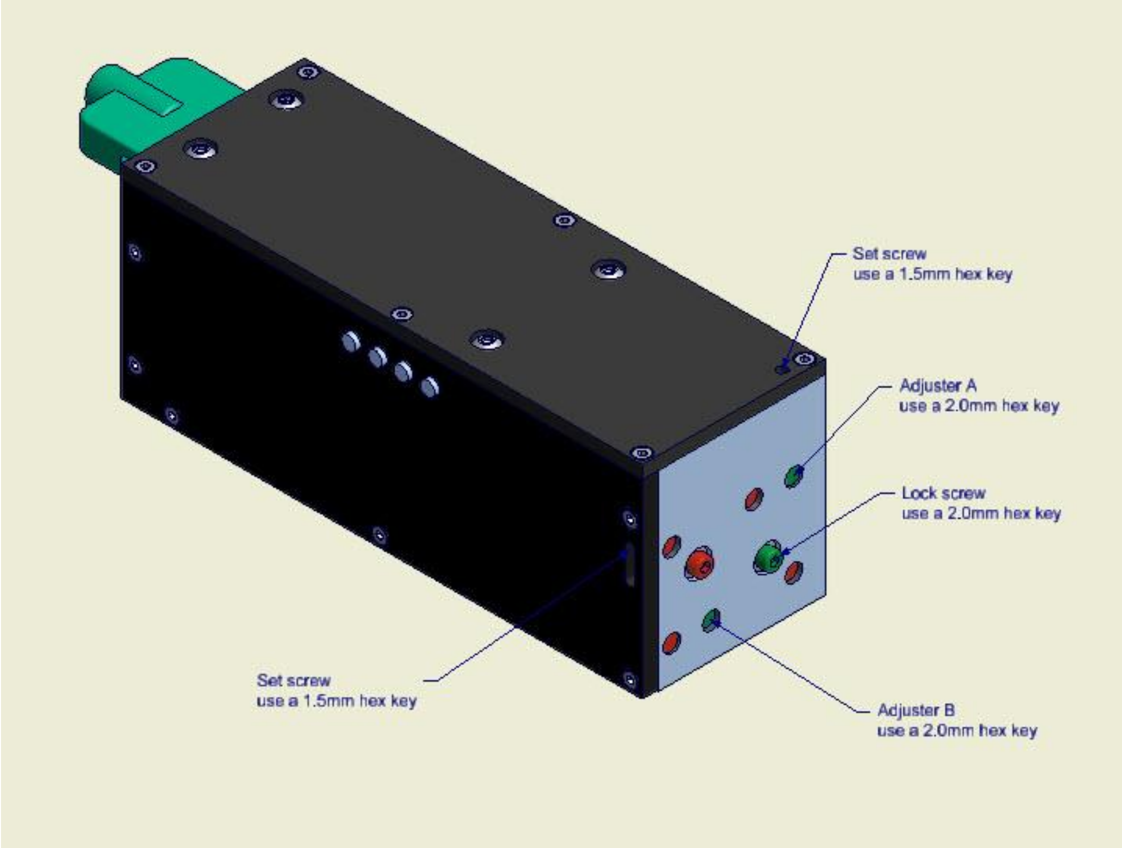
This problem is often caused by incorrect beam-splitter alignment. To re-align the sensor, first ensure that the beam splitter is correctly installed on the system. The beam splitter should make an approximately 45 degree angle with the incoming laser beam.

Select a low-magnification lens (such as 2x or 5x). Adjust the beam splitter's position until the laser is in the center of the review camera's field of view.

Solution Step 5b

This could also be caused by the sensor's sideways alignment. Complete the following steps to re-align the sensor:

1. Bring sensor into focus
2. Rotate the Lock Screw counter clockwise by a **half turn**. This will unlock adjuster A. **Failing to unlock the adjuster before turning it will damage the adjuster.**
3. Turn adjuster A (see diagram) slightly while observing the laser power. Continue turning the adjuster slowly until a minimum in laser power is found. **NOTE: Adjuster A should never be turned by more than 1 full rotation as this can damage the sensor.**
4. Move the adjuster slowly to the left and right to establish a range over which the laser power remains at its lowest point. Move the adjuster to the middle point of this range.



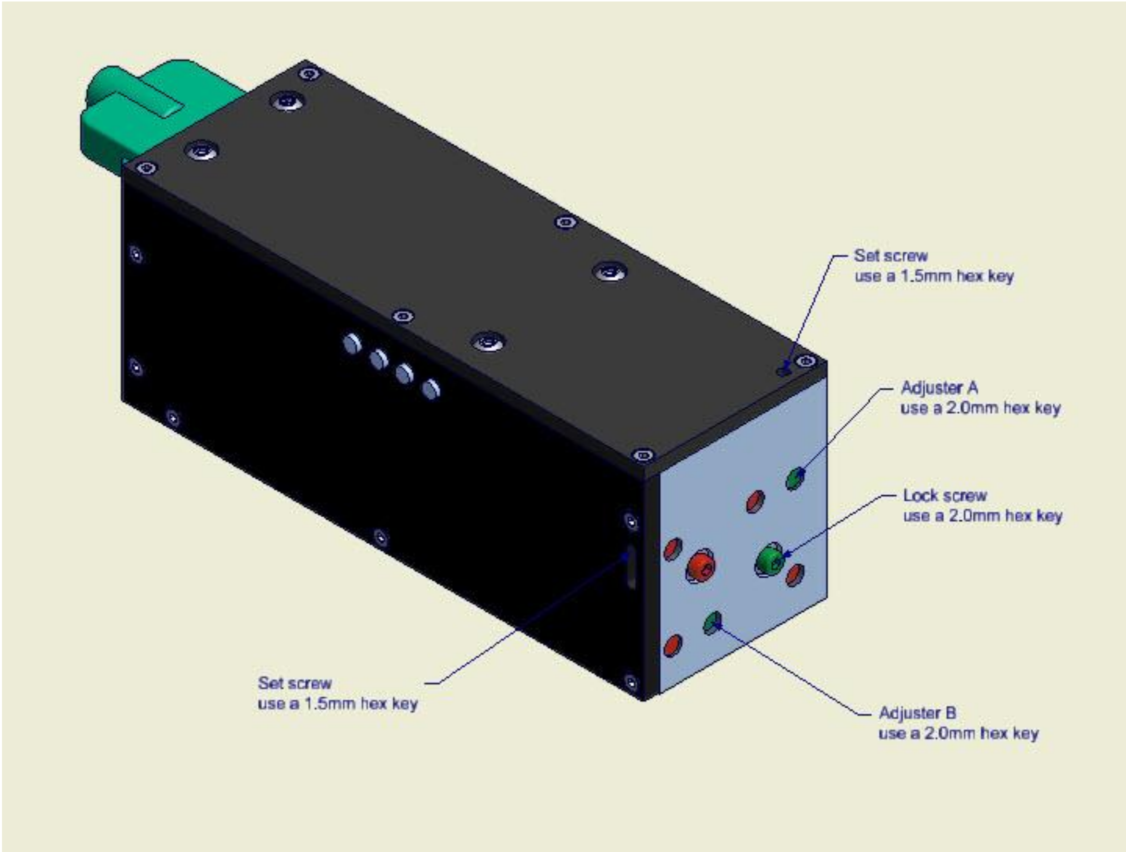
Screws and Adjusters. Adjuster A is labelled in red.

Issue 6 – Scanline is very distorted or displaying an incorrect shape

Solution Step 6a

A “bad” scanline can sometimes be fixed by adjusting the sensor’s alignment. Complete the following steps to re-align the sensor:

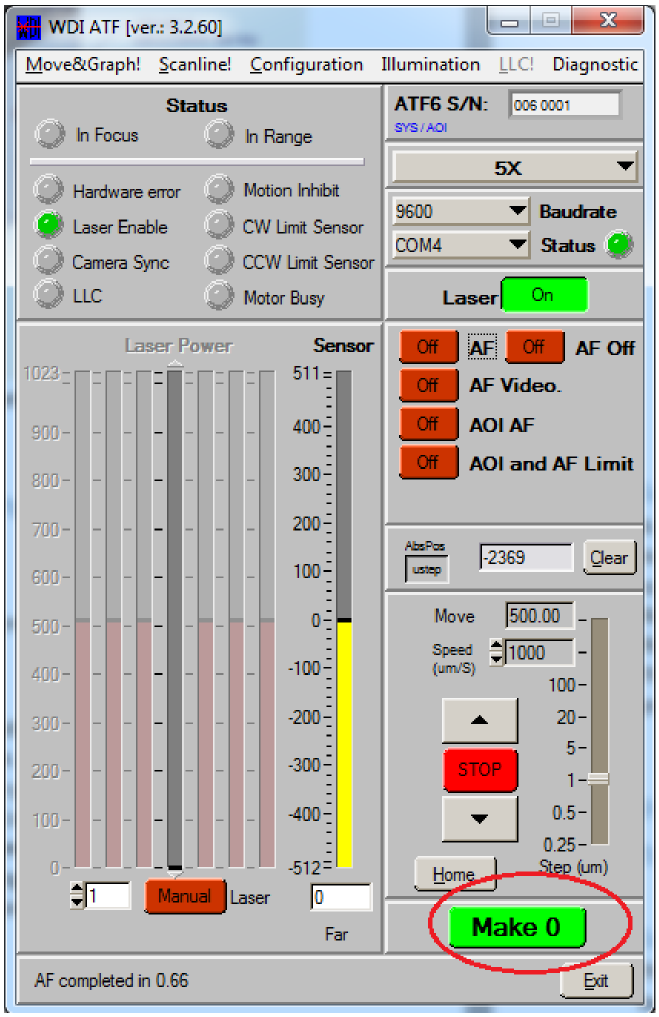
5) Bring sensor into focus
6) Rotate the Lock Screw counter clockwise by a **half turn**. This will unlock adjuster A. **Failing to unlock the adjuster before turning it will damage the adjuster.**
7) Turn adjuster A (see diagram) slightly while observing the laser power. Continue turning the adjuster slowly until a minimum in laser power is found. **NOTE: Adjuster A should never be turned by more than 1 full rotation as this can damage the sensor.**
8) Move the adjuster slowly to the left and right to establish a range over which the laser power remains at its lowest point. Move the adjuster to the middle point of this range.



Screws and Adjusters. Adjuster A is labelled in red.

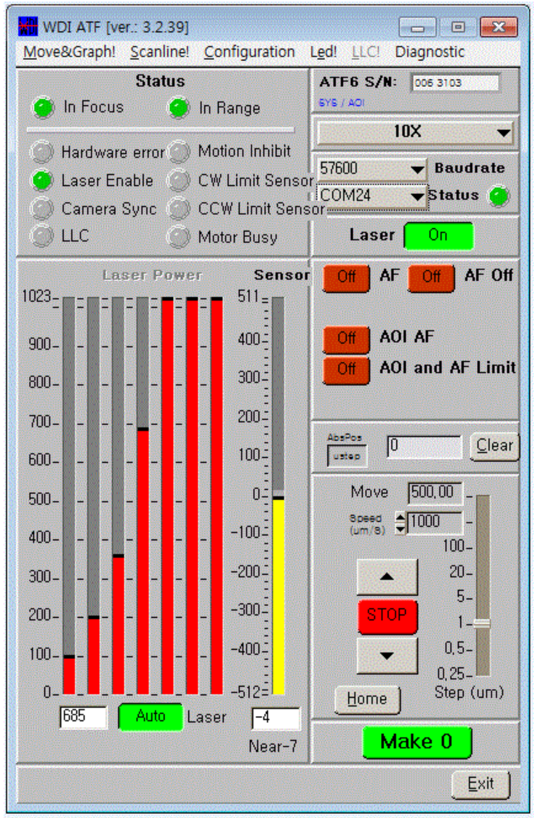
Solution Step 6b

A distorted scanline can also be caused by saturation of the sensor by front light illumination. To fix this issue, bring the sample into focus, then switch the illumination off. Click Make0 in the console. Open scanline and check for distortion. If no distortion is present, the likely cause of distortion is the illumination. Switch on the illumination at the lowest possible level, and then gradually increase the illumination intensity while monitoring the scanline. Keep increasing the intensity until scanline distorts. The illumination will need to be kept below this distortion level to maintain clear scanline. If this is not possible for your application, please contact WDI.



The Make 0 button.

Issue 7 – Sensor power is unequal across segments (Does not apply to ATF4)



Example of unequal laser segments.

Solution Step 7a

This is typically caused by Beam Splitter misalignment. To re-align the sensor, first ensure that the beam splitter is correctly installed on the system. The beam splitter should make an approximately 45 degree angle with the incoming laser beam.

Select a low-magnification lens (such as 2x or 5x). Adjust the beam splitter's position until the laser is in the center of the review camera's field of view.

Issue 8 - Scanline graph is not visible in the scanline window.

Solution Step 8a

This problem typically means that the sensor is not receiving any signal. This can be due to misalignment of B/S splitter and sensor, causing the laser dot to be pushed outside the sensor's FOV. To re-align the sensor, first ensure that the beam splitter is correctly installed on the system. The beam splitter should make an approximately 45 degree angle with the incoming laser beam.

Select a low-magnification lens (such as 2x or 5x). Adjust the beam splitter's position until the laser is in the center of the review camera's field of view.

Solution Step 8b

This issue can also be caused by a faulty laser. Remove the sensor from the mounting, without unplugging it. Use a piece of paper (or an IR Card for sensors with a 785nm laser) to check that the ATF laser is functioning. This can be placed either directly in front of the ATF sensor's lens, or in front of the microscope's objective. If there is no visible light and the laser interlock is nonactive, the laser diode has malfunctioned. In this case, the sensor should be returned to WDI for repair. If there is a visible laser spot, but the scanline is still not present, move to the next Solution Step.

Solution Step 8c

Place a mirror in front of the sensor's output lens while monitoring the Scanline window. The scanline should be clearly visible. If it is not, there may be an internal malfunction with the sensor. Please contact WDI for more information.