First Ten Ångstroms

Introduction to the FTA4000

This document will help you get started with your new FTA4000.

The FTA4000 is optimized for contact angle measurements using very small droplets on small samples. It uses a special piezo pump to control liquid flow without the usual backlash problems of mechanical syringe pumps. A high power zoom microscope provides fields of view down to less than 200 microns. The sample stage can simultaneously accommodate several samples of a centimeter size. It also has special provisions for imaging paper at high magnification.

Internal view of instrument. Optional alignment looks down from upper right.

Overview of Capabilities

The instrument has three main components all mounted on a single vertical surface plate for stiffness and optical stability. The entire instrument is housed in an enclosure with doors to provide additional environmental and stray light control.

• Piezo pump: this pump has a maximum single-stroke capacity of 4 microliters but can control dispense droplet volume down to 5 picoliters using the patented NanoDispense technique. It has a high resolution stepper to position it in the Z direction with 3.175 micron resolution and manual micrometers to position it in X and Y.

• Sample stage: a rotary stage is fitted with a stepper motor driven Z axis with 3.175 micron resolution. The Y direction, along the optical axis, is adjusted with a manual micrometer. The X position is fixed so the center of the stage is on the optical axis. The rotary stage provides a convenient way of moving a number of samples, mounted around the periphery of the stage, into the measurement position within a small overall spatial volume. The stage also carries two vials for user test liquid that the piezo pump can aspirate from and then dispense onto the sample. Stepper motor driven X and Y are available as an option for precise positioning of samples with small features.

• Optical system: the main microscope is a high power zoom that views the sample horizontally. It is fitted with a sensitive monochrome camera with 640 × 480 pixel resolution. A focused high intensity red LED is the backlight source. The combination of the intensity of the backlight and the sensitivity of the camera gives fully illuminated images even at maximum magnification. An alignment microscope is fitted so that it looks down on the top of the sample from a 60° angle with respect to horizontal. This allows the droplet to be precisely placed on small features.

Power and Computer Connections

The FTA4000 can be powered from either 100/120VAC or 220-240VAC. The current draw is 1A at 120VAC or 0.5A at 240VAC.

Fuses are installed on both sides of the AC line in the power entry module on the rear of the cabinet. The power entry module also contains an on/off switch. The on state is indicated by a green LED just above the switch.

The instrument is controlled from a host computer through an RS-232 line. The 9 pin D cable must be connected to an available serial port on the host computer.

Finally, video is carried to the host computer through a BNC coax cable from a rear panel connector. The computer end of the cable will match the connector on the frame grabber. The USB 1.1 cable from the alignment camera goes directly to an available USB port on the computer.

Configuration File

All settings in the software are preserved in a single file called the configuration, or config, file. The file is an Access database file and so its extension must be mdb. The default name for this

file is simply default.mdb, but it can be renamed on the LogOn screen. You can have more than one config file and select which one to use on the LogOn screen. A copy of the config file used at the factory to test your instrument is included with your documentation. It is strongly recommended that you copy the factory file to your application directory after you have installed the software but before you run Fta32 Video for the first time. Then the software will start with all settings correct.

Camera and Microscope Setup

The camera and microscope normally require no user setup. The main analytical microscope is a 12× zoom with either a horizontal or 3° look-down orientation. The 3° look-down is achieved by using the second set of mounting holes on the vertical surface plate for the microscope support brackets. An optional alignment microscope looks down at 60° onto the sample to assist in locating drops on samples with small features. The photo at the beginning does not show this option.

The camera has a 1/3 inch format with a 4.8mm × 3.6mm CCD. The field of view of the microscope, i.e., the area imaged, is the size of the CCD divided by the total magnification of the microscope. The camera should always be operated with automatic gain control (AGC) on and back light compensation (BLC) off.

The standard analytical microscope consists of the following optical components:

- a 2.0× magnification auxiliary lens to provide a working distance of 35mm,
- a 12:1 zoom cell with magnification from 0.58× to 7.5×,
- a 2× adaptor tube,
- a C-mount adaptor for the camera, providing a
- field of view 2.05mm × 1.55mm down to 170 microns × 125 microns.

The microscope has two manual controls:

- zoom magnification in the middle of the zoom cell, and
- focus at the end of the zoom cell nearest the object.

No iris is furnished because maximum light is required at the high magnifications employed.

The microscope consists of the following optical components:

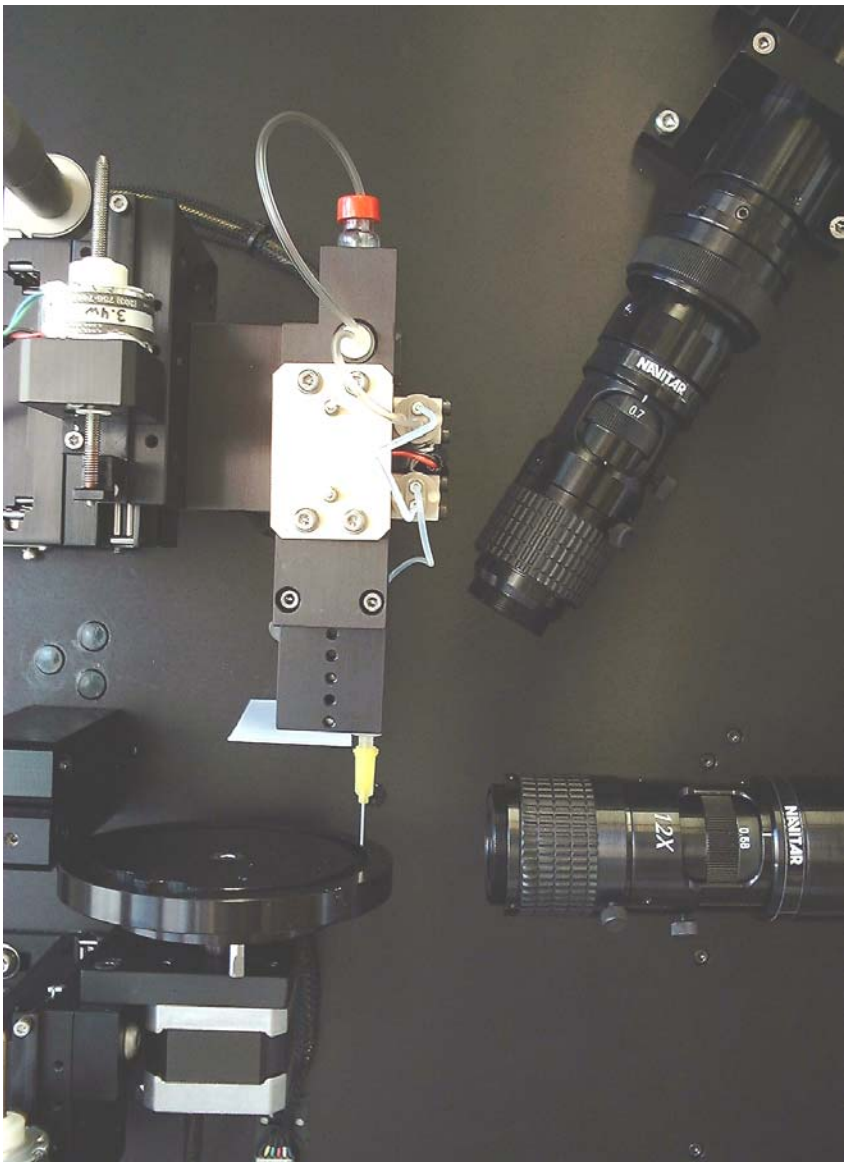
- a 6:1 zoom cell with magnification from 0.7× to 4.2× with 93mm working distance,
- a 1x adaptor tube,
- a C-mount adaptor for the ¼ inch USB 1.1 camera, providing a
- field of view 6mm × 4.5mm down to 1mm × 0.75mm.

The alignment microscope has three controls:

- an aperture (iris), the ring closest to the camera; twists from open to closed through 90°,
- zoom magnification in the middle of the cell, and
- focus at the end of the cell nearest the object.

The alignment microscope has lower magnification and needs the iris to deal with looking at the sample from a high angle. The iris increases the depth of field and helps keep both the near side and the far side of the sample, which are at different distances because of the viewing angle, in focus.

Piezo Pump



Closeup of the piezo pump.

The piezo pump carries its own source of liquid, which we refer to as the “system liquid”, in a 12mm vial above it, with the red cap in the photo. This can be used as the dispense liquid or, in with the NanoDispense method, the dispense liquid is aspirated externally into the dispense tip but is always separated from the system liquid by an airgap. In this latter case, the system liquid simply fills the remainder of the pump with an incompressible fluid and makes it efficient.

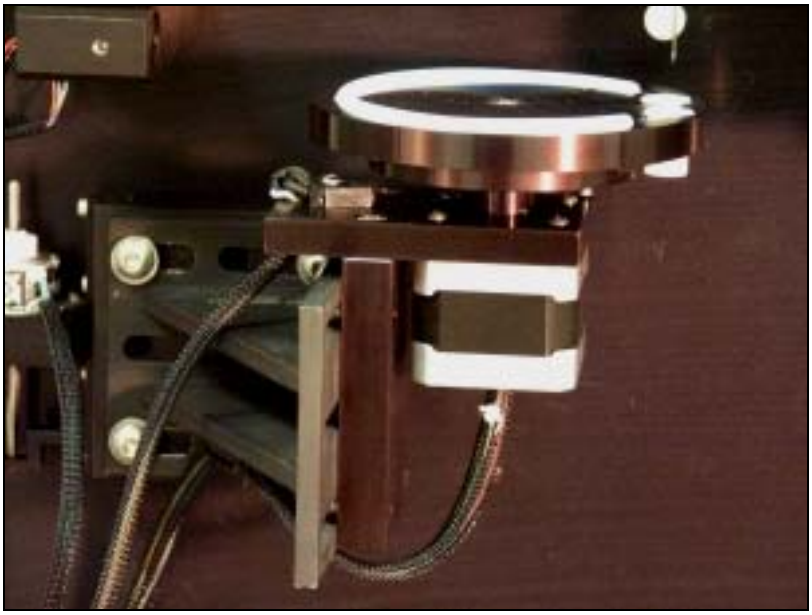
The system liquid passes through a 35 micron filter before entering the inlet valve of the pump. Solenoid inlet and outlet valves control the flow direction through the pump. The outlet valve feeds a union into which a Luer adaptor fits at the bottom. A yellow Luer-hub needle is seen in the photo. The tubing is arranged so that any bubbles will float in the direction of normal pumping and tend to be swept out rather than remain trapped inside.

The piezo pump can be used in two fundamentally different ways, which will be discussed further below:

- classic direct dispense, as if it were a very high resolution syringe pump, or

- the new NanoDispense method where the volume is dispensed by carefully touching-off liquid from a spherical cap preformed on the dispense tip.

Sample Stage



Closeup of the rotary sample stage with Teflon rod ring in place.

The sample stage is a rotary stage 100mm in diameter. The table is fixed to the center drive by a single M6 flat head screw so

- it is easily removed for loading samples externally, and
- it may be replaced with the user's stage if desired.

The rotary stage is directly driven by a microstepped motor with 0.225° resolution. The stage will contain, in general, three regions around its periphery:

- two user test liquid vials, which can be removed if desired,
- a region for flat user samples, and
- the removable Teflon ring, visible around most of the periphery in the photo.

The replaceable Teflon ring snaps into place and can be removed or cut down in length. It provides a mold to shape paper samples for clearer viewing at high magnification. Papers are often rough at the magnifications needed for small drops, so placing a small bend along the Y axis over the Teflon ring greatly improves sessile drop visibility since the drop is at the top of the bend.

The total length around the periphery is about 300mm, so a fair number of small samples can be mounted and rotated into position.

Drop Delivery Methods and Capabilities

The FTA4000 provides two different dispense mechanisms for different volume regimes. For volumes in the range from a few microliters down to a few tens of nanoliters, a classical pendant drop can be formed on the dispense tip. This is a drop that distinctly hangs down. If you inspect its profile, it typically displays a distinct maximum diameter below the tip. When this drop is touched-off onto the sample surface, the liquid hanging down from the tip detaches in a more or less complete fashion. The deposited volume is similar to the volume hanging down before the touch-off.

For volumes smaller than a few tens of nanoliters, the classical pendant drop touch-off does not work because of the consequences of the Laplace formula pressure. Instead, FTA provides the NanoDispense protocol. This protocol forms a small spherical cap on the dispense tip prior to touch-off. The tip is then lowered a precise distance towards the surface so the bottom of this spherical cap just touches the surface. The liquid then wets the surface and spreads to a diameter similar to the tip diameter. This is sensed by the image processing system which then raises the tip rapidly. In so doing, the lamella that is formed pulls enough liquid out of the tip to ensure a full, or advancing, contact angle.

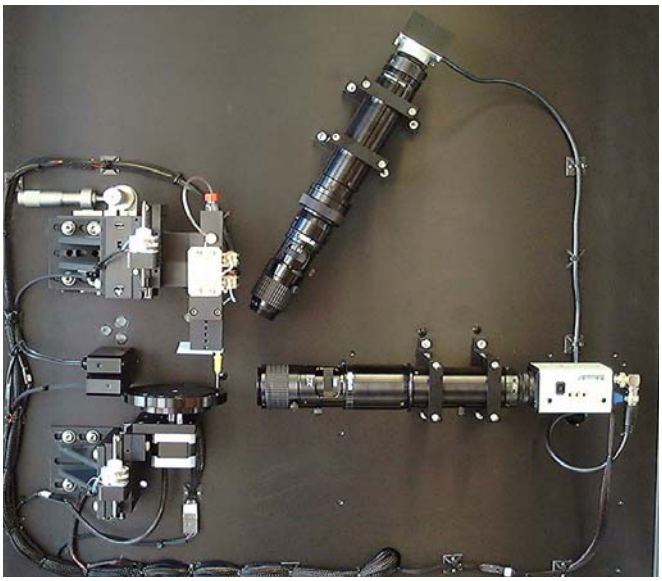
The following table relates sessile drop volume and diameter to contact angle for two representative angles, 30 and 90°.

Volume	Spherical Drop Diameter	30° Sessile Drop Base Width	90° Sessile Drop Base Width
10 picoliters	26.7 microns	57.1 microns	33.7 microns
100 picoliters	57.6 microns	123 microns	72.6 microns
1 nanoliter	124 microns	265 microns	156 microns
10 nanoliters	267 microns	571 microns	337 microns
100 nanoliters	576 microns	1.23 millimeters	726 microns

Alignment Microscope

The alignment microscope helps the user place small drops on specific features of their samples. It provides a video image of the dispense tip above the sample. This image has enough resolution to locate the tip, yet has high depth of field to image the sample at the 60° viewing angle. The drop can be placed at the desired point on the sample by the following protocol:

- the needle is manually positioned in X, left and right, using its stage micrometers so it is in the center of the image.
- the needle is manually positioned in Y, towards or away from the main microscope, so it is over the desired sampler feature.
- the microscope is focused on the dispense tip.



Front view of instrument. Instrument is built on a vertical surface plate for stability.

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