TURBO FT™
PORTABLE FT-IR SPECTROMETER

INSTRUCTION MANUAL

<u>Table of Contents</u>

System Description

The Turbo FT Portable Field Spectrometer is a complete person-portable infrared spectrometer, consisting of a sensor head and portable computer. The sensor head includes a miniature interferometer, with input optics and infrared detector, drive and sampling electronics, and temperature controllers. The portable computer contains all data acquisition and interface electronics required for driving the sensor head, and runs the D&P proprietary display and control software. The software acquires and displays data, provides various processing functions, and stores data on an internal hard disk. A writeable CD/DVD, USB memory device, or LAN connection can be used to transfer data to another computer. The software is controlled via a keyboard or mouse commands, with all data displayed on a built-in LCD screen. The entire instrument is ruggedized and protected from the environment, allowing its use in the harsh conditions in the field.

Optical Subsystem

The core of the spectrometer is the proprietary D&P rotary interferometer. This contains infrared optics, beam splitter, and a rotating refractor assembly. Input light passes through the fore optics, an aperture, and a lens (which also seals the unit) into the interferometer. The rotating refractor is servo driven at a constant speed, producing the interference patterns. There are four interferograms per revolution of the refractor. Because of the rotary nature of the scan, high spectral rates can be achieved, ranging from 25 to 100 scans per second. The modulated output light passes through a focusing lens (which also seals the unit) onto an infrared detector in a liquid nitrogen (LN_2) Dewar. The standard detector is a Mercury Cadmium Telluride (HgCdTe, or MCT), which has a spectral range of approximately 5-16 micrometers. An optional detector is a dual element, consisting of the standard MCT in combination with an Indium Antimonide (InSb). This dual detector has a spectral range of approximately 2.5 to 16 micrometers.

The detector must be filled with liquid nitrogen before use, using the funnel provided. Be very careful when filling the detector, and always wear gloves and eye protection. The best technique is to put in about three funnels, then let the detector cool for a while. It will eventually spout a plume of vapor as the internal Dewar surface is finally cooled to 77 degrees K. After that, more liquid nitrogen must be added to fill the Dewar nearly to the top. If too much LN_2 is added initially, the Dewar may spout liquid nitrogen and spray it up out of the filling hole. Do not put any exposed body parts near the detector fill hole when filling the detector. Severe frostbite can result!

The interferometer is monitored by a temperature controlled laser diode (LD) reference channel. It provides the reference for the sampling electronics, and thus the wavelength calibration for the spectrum. The temperature set point for each laser diode is internal, and is preset at the factory. Since the temperature of this laser diode determines its wavelength, sufficient time must be allowed after powering the unit for this controller to reach its set point. Depending on the ambient temperature, this is usually less than 1 minute.

The detachable fore-optics are used to aim the instrument at a target visually, and direct target energy into the input of the interferometer. It is a two piece assembly, having a separate eyepiece assembly and rotating input optic. The standard input optic is 1 inch in diameter, with a 4.8 degree field of view. This gives a 3-inch diameter spot at about 3 feet away. An optional 2-inch diameter input optic can be used, which has a 2.4 degree field of view. There are multiple positions of these input optics for viewer focusing. The first stop, farthest out, is used for close range, which is good for most tripod work, looking at the ground. The other stops, further in, are focused from about 10 feet to infinity. The input optic snout can also be used for aiming by rotating it. To view a target,

the small lever in the base of the eyepiece assembly is pulled up to provide "through the lens" viewing of the target. To take data, the lever should be dropped down. This directs the input through to the spectrometer. Blackbody accessories for either of these fore-optics are available, allowing calibrated measurements of temperature and emissivity.

A 4 inch fore-optic is also available. It has a 1.2 degree field of view and also allows through-the-lens viewing of targets. It is a one piece unit, with no swivel at the end. There is no blackbody available for this fore-optic. A 4 inch blackbody element would be very large and bulky, and require significant power to achieve normal calibration temperatures in a reasonable amount of time.

Electronic Subsystem

The standard electronic subsystem for the interferometer consists of a set of two printed circuit boards. One drives the rotating refractor in the interferometer and provides the control signals used throughout the system. The other performs detector signal conditioning and interface to the analog to digital converter, which is located in the system computer. All sensor head power is provided from the computer.

The servo function drives the rotor at a constant speed, using an internal interferometer signal as a reference. The detector electronics provides proper power to the detector, filters the IR signal at the appropriate cutoff frequency, and drives the analog to digital converter in the system computer. It also contains the diode laser channel electronics. A high bandwidth preamp and digital signal circuit provides the sampling signal.

Temperature Control

There are three temperature controllers in the instrument. One controls the temperature of the laser diode (LD), maintaining it at a precise internal set point, which then holds the laser reference wavelength at a precise value. This will come on for a time when power is first applied to the instrument. No data should be acquired while the LD is being driven to its set point, as it would be uncalibrated in wavelength. This time is short, about 1 minute.

A second controller holds the temperature of the interferometer constant, which aids in maintaining a precise calibration as the ambient temperature changes. This temperature controller is initially turned on and set automatically to the temperature at turn-on of the instrument. The set point can be changed by the user, or the controller can be turned on and off, under the Instrument-Temperature software menu. A change in set point may become necessary if the ambient temperature changes dramatically during an extended acquisition period. Re-setting the temperature may require a stabilization time of 30-60 minutes. It should be noted here that the temperature control has an easier time heating than cooling. For this reason, the instrument temperature should never be allowed to get below 5 degrees C of the ambient temperature. This condition could cause the controller to draw excess current, overheat, and possibly damage the electronics. Generally, if very high (above 35 C) or very low (below 15 C) temperatures are expected during measurement, it is best to preheat the system for an hour or more before taking it out. The set point chosen should be 1 or 2 degrees above the highest expected temperature of the measurement period.

The third temperature controller is for an optional stabilized blackbody accessory. The blackbody device connects externally. It is used to calibrate the spectrometer for certain kinds of measurements, such as radiance and emissivity. The set point and on/off control for this is also done in software, under the Instrument-Temperature software menu. The three temperatures of these

controllers, and a fourth temperature sensor located inside the white enclosure, are read out in a status line at the bottom of the screen. They are also stored with the data.

Temperature Alarms

There is a temperature monitoring function in the software that will warn of certain temperatures in the system being out of range. This will be evidenced by an audible alarm and flashing messages on the screen. The **<alt>F9** key silences the alarm. There are three alarm conditions:

1.) The instrument temperature control is on, and the instrument temperature is different from the set point by the tolerance set under Factory Setup (<alt>F10). The recommended setting is 5 degrees. Any larger can result in damage to internal electronics;

2.) The instrument temperature is beyond the limits set under Factory Setup (<alt>F10). The instrument is designed to run between 15 and 35 degrees C;

3.) The ambient air temperature inside the instrument enclosure is beyond the limits set under Factory Setup (<alt>F10). The air temperature for normal operation should always be between 5 and 40 degrees C. Otherwise, components can be damaged.

The user can silence the audible alarm with the **<alt>F9** key. This will turn off the audible alarm, but the on screen flashing messages will continue until the alarm condition is fixed. The alarm for the instrument set point condition can be fixed by resetting the instrument temperature set point. This is done in the Instrument-Temperature software menu function. The alarms for instrument and ambient temperature limits have a built in hysteresis of two degrees C. Therefore, the instrument temperature must be brought up to 17 or down to 33 degrees C to de-activate that alarm. Similarly, the ambient air temperature would have to be brought up to 7 or down to 38 degrees C to de-activate that alarm. Once an alarm is de-activated, the dialog box and audible alarms are also reset.

System Computer

The computer supplied with the Turbo FT is a portable type, with expansion slots. The power supply in the computer is used to power the entire electronic package in the sensor. The computer contains all the functions of a PC type computer, including RAM, hard disk, keyboard, mouse, serial, parallel, USB, LAN, and external VGA.

The field keyboard is sufficient to run all software functions, and provides the quickest method to adjust parameters and process data. The mouse function is generally integrated with the keyboard as a mouse pad, but that can vary with the computer system supplied. No mouse is required to run, but one can be used if desired. A printer can be connected to the USB or parallel port for hard copy. The CD/DVD, USB, or LAN ports are used to get data off.

Software Operation

The software runs under Windows XP, and is designed to be used either with or without a mouse. A mouse makes some operations quicker, but is not necessary, as most functions can also be accessed easily via the keyboard. Note that the File/Open dialog box currently requires a mouse to navigate. In general, either a function key, single underlined character in a menu item, or one of the

cursor arrow keys can be used to navigate the screens. The ESC key generally backs out of a function, and the TAB and <shift>TAB keys are used in some screens to move forward or backwards. Every effort was made to facilitate use in the field without a mouse or other pointing device, yet still allow one when operating in more of a laboratory or other inside environment.

The main menu items are across the top of the screen, and are accessed using the mouse or using the <Alt> key and the first (underlined) letter of the title. They are:

File   Instrument   Display   Process   Help

Each of these menu items has a drop down submenu of available functions, which will be described in turn below. There are also 11 function keys assigned for the most commonly used repetitive operations. Their functions are listed in a row of boxes located just below the main menu titles at the top of the screen. Either the function key or mouse click on the box activates them. The Function key assignments are:

F1-Acquire   F2-Open   F3-Save As   F4-Refresh   F5-Export   F6- Run
F7-Cursor   F8-X scale   F9-Y scale   F10-Status
<alt>F8 – Diagnostic 2X2+1 Display
<alt>F9 – Disable Temp Alarm
<Alt>F10 – Factory Setup

The middle of the screen is used for graphics, either one or two plots, depending on the plot type selected under Display-Plot Type.

When a plot is being displayed and no cursors or menus are active, the arrow keys are used to change plot scales in X or Y, in factors of 2. When used with the "Ctrl" key, the arrow keys will pan the display in X and Y to different plot regions one-quarter screen at a time. The operation is as follows:

Right arrow (>) = Zoom In X scale 2X   <Ctrl> Right arrow [ctrl+>] = Pan plot ¼ right in X
Left arrow (<) = Zoom Out X scale 2X   <Ctrl> Left arrow [ctrl+<] = Pan plot ¼ left in X
Up arrow (^) = Zoom In Y scale 2X   <Ctrl> Up arrow [ctrl+^] = Pan plot ¼ up in Y
Down arrow (v) = Zoom Out Y scale 2X   <Ctrl> Down arrow [ctrl+v] =Pan plot ¼ down in Y

Using the File-AutoName feature:

Plus (+) = move forward through a file sequence (hold down for rapid sequencing)
Minus (-) = move backwards through a file sequence (hold down for rapid sequencing)
Using <ctl> key with either + or – will sequence through every 10th filename.

The bottom of the screen is used for one line of information display, including system temperatures on the left, and messages on the right.

There are various file types used in the software. Raw binary data is saved in one of six types of files, with distinct extensions. They are:

Setup File (.INI)   used to store instrument setup
Sample (.SAM)   used in all types of processing
Reference (.REF)   used in ratio, difference, inverse, and absorbance
Cold Blackbody (.CBB)   used in radiance and emissivity processing

Warm Blackbody (.WBB)   used in radiance and emissivity processing
Down-Welling Radiance (.DWR)   used in emissivity processing

  Both raw and processed data can be exported as ASCII text files or .SPC files, so it can be imported into other applications for further processing and/or display. The ASCII file extensions all end in X. There are eleven types of exported files:

Sample (.SAX)   raw sample
Reference (.REX)   raw reference
Warm Blackbody (.WBX)   raw warm blackbody
Cold Blackbody (.CBX)   raw cold blackbody
Downwelling Radiance (.DWX)   raw downwelling radiance
Ratio (.RTX)   processed ratio SAM/REF
Difference (.DIX)   processed difference SAM-REF
Inverse (.INX)   processed inverse 1-SAM/REF
Absorbance (.ABX)   processed absorbance -log (SAM/REF)
Radiance (.RAX)   processed radiance
Emissivity (.EMX)   processed emissivity

The .SPC files for all of the above types of data all end in .SPC

File Menu

  The File menu has 7 items in its submenu, selected by mouse, arrow key, or underlined letter. They are:

   Open   Save As Save Settings   Data File Name and Directory
   AutoName Print   Exit

File Dialog Box

  Some of entries under File, and elsewhere in the software, refer to bringing up a "File Dialog Box". Its appearance and operation are explained here. There are four sections in this box. Moving between sections can be done with the mouse or, if the keyboard is being used, the TAB key (to move forward) or <shift>TAB key (to move backward). To move within a section, the mouse or cursor key is used. The first section of this dialog box contains the directories available. The second section of this box lists various files in the current directory. They may be selected and traversed as desired. The third section will contain the file selected. The fourth section lists the currently active mask for file extensions. Once a file is highlighted, the Enter key selects it into the Filename box, and it can be opened or saved to by then selecting OK.

Menu Selections

  File-Open first brings up a small dialog box containing the valid file types, as determined by the current settings for the Math function under Process. For all Math functions except Radiance and Emissivity, the choices are Sample or Reference. For Radiance, the choices are CBB (Cold

Blackbody), WBB (Warm Blackbody), or Sample. For Emissivity, the choices are the same as Radiance, with the addition of DWR (Down-welling Radiance) type files.

Once a file type is selected, the File Dialog Box appears, with the mask for the file type selected. All files of that type in the current directory will be displayed in the center of the file dialog box. Any annotation saved with the file, and selected header information, is printed in a display window that opens below the File/Open dialog box. The operation of the File Dialog Box is explained at the beginning of this section.

File-Save As works very much like Open, bringing up a small dialog box to choose a file type to save under, again having selections that depend on the Math selected under Process. For all Math functions except Radiance and Emissivity, the choices are Sample or Reference. For Radiance, the choices are CBB (Cold Blackbody), WBB (Warm Blackbody), or Sample. For Emissivity, the choices are the same as Radiance, with the addition of DWR (Down-welling Radiance) type files.

Once a file type is selected, a dialog box appears for an annotation to be added to the data in the file. A line of text can be added in the long text box. The next step will bring up the File Dialog Box, with the mask set for the file type selected. All files currently stored in the current directory with that mask will be displayed in the center section of the File Dialog Box. One of these can be used, or a new name typed in. The operation of the File Dialog Box is explained at the beginning of this section.

Save Settings has no submenu. It is used simply to save the current instrument settings into the default setup file TurboFT.INI, which is loaded when the program starts. It has the same effect as the "Save Settings and Exit" when leaving the program, but does so without exiting.

Data File Name and Directory brings up a File Dialog Box. This is used to create and specify directories for data to be read from and stored to. A name entered in the File name box will be used as the root name for the AutoName function. If AutoName is enabled, a four digit number will be appended to that root name and files will be saved with auto-incrementing numbers. The appropriate three-character extension for the data type being saved will be added to the filename. File types (i.e. SAM and REF) can be mixed within a given root name, and annotation can be added at the time of saving the file. A prompt will appear at the time of the file save indicating the filename and extension used.

AutoName controls the automatic file naming function. When turned on, this will automatically generate sequential filenames when taking large data sets quickly. When this menu item is selected, the choices are to Activate (Off or On), and OK, CANCEL. A dot appears next to Off or On to indicate whether AutoName is enabled or disabled. The root name must be entered in the Data File Name and Directory section of the File menu. If AutoName is enabled, a six digit number will be appended to the root name, and files will be saved with auto-incrementing numbers. The appropriate three-character extension for the data type being saved will be added to the filename. File types (i.e. SAM and REF) can be mixed within a given root name, and annotation can be added at the time of saving the file. A prompt will appear at the time of the file save indicating the filename and extension used.

For Sample data, this feature is used with Continuous Acquisition. Using the AutoName option with the Continuous Sample Acquisition will generate files at a rapid rate. Using AutoName, File names consist of a root name, a sequence number and an extension. The sequence number runs from 000000 to 999999. A new root name will start the sequence at 000000. When the sequence number approaches the upper limit a warning will appear on the bottom of the screen. The warning is in 4 levels. When there are less than 1000 sequence numbers available, a text message to this

effect is displayed at the bottom center of the screen. With less than 500 sequence numbers left a Green bar surrounds the text warning. With less that 100 sequence numbers left, a RED bar surrounds the text warning. With less that 2 sequence numbers left, a Purple bar surrounds the text warning. When there are no sequence numbers left, the acquisition is stopped and a request fore a new root name is displayed on the screen.

A similar warning is displayed if available disk space is less than 1 GB. At 1 GB a text warning appears. At less than 500 MB the text appears with a GREEN bar, less than 100 MB the text appears with a RED bar and less than 50 MB the text appears with a Purple bar.

Both conditions are checked at the same time and the bar color corresponding to the more sever condition is used with text warnings for each of the critical conditions.

To sequence through a series of files taken, the user selects any filename in the sequence with F2 or File-Open, then uses the + or - key to move forward or backward in the file sequence. Holding either key down will advance quickly through the sequence, essentially re-playing the acquisition. Using the <ctl> key with either + or – will jump 10 filenames at a time.

Print will bring up a standard Windows printing dialog box, then print the screen contents. A printer must be connected and installed into Windows prior to running this function.

Exit will terminate the program, but will first prompt the user whether to save current instrument settings into the TurboFT.INI file, or exit without saving. The same action can be invoked with the <Alt>X keystroke combination.

Instrument Menu

The Instrument menu has 5 items in its submenu, selected by mouse, arrow key, or underlined letter. They are:

Coadds   Resolution   Zero Fill   FFT Apodization   Temperatures

When Resolution, Zero Fill or Apodization settings are changed, any open data files are recomputed with the new settings. When new data are acquired or data files are opened, these settings are used to compute the associated spectra. Files that are subsequently Opened or Acquired are computed with these new settings.

Menu Selections

Coadds sets the number of spectra to be averaged into a coadded spectrum. Noise can be reduced by the square root of the number of coadds. Coadding takes extra time in data acquisition, and also results in larger data files, since all interferograms are saved to allow reprocessing at a later time. Selecting this brings up a dialog box with two entry fields. The first is the number of coadds for Sample files, which can be set from 4 to 10,000. The second field is for all other file types, and can be set from 4 to 1,000. The present number of coadds is displayed in each field. To change the number, select the box with mouse or cursor arrow keys and type the new value followed by Enter. Valid numbers for both must be multiples of 4, which corresponds to 1 revolution of the rotor.. Selecting OK sets the new value; Cancel retains the old value.

Resolution is used to specify the size of the FFT performed, and thus the resolution of the resulting spectrum. The number of points collected is not changed, and all interferogram data is stored in the raw data file, so any spectrum can be reprocessed later at a different resolution. Selecting this item brings up a dialog box with the choices for resolution (in cm^{-1}) on the left, with the current setting indicated with a dot. Clicking on any other setting with the mouse, or moving there with the arrow keys and hitting Enter will change the selection. On the right side is the OK, CANCEL selection. If this setting is changed, an automatic recalculation of all relevant spectra will be performed.

Zero Fill is used to generate higher plot resolution at any spectral resolution. The raw FFT resolution in some cases can be quite coarse, and yield poor line-shape. By zero filling the interferogram to a larger FFT size, more points are generated in the FFT, giving better line-shape and smoother looking plots. The maximum FFT size in the instrument is 32,768 points. The scan length determines the maximum spectral resolution. The choices shown under this menu are:

> None   no zero filling
> 2X   interferogram filled out with two times the number of points
> 4X   interferogram filled out with four times the number of points

If this setting is changed, an automatic recalculation of all relevant spectra will be performed.

FFT Apodization sets the weighting function to be used to window the interferogram data before performing the FFT. Selecting this item brings up a dialog box with a list of 6 possible functions. The currently selected function is marked with a dot. The choices listed are:

> None
> Triangle
> Hanning
> Hamming
> Blackman
> Gaussian

In general, the apodization to be used depends on whether it is more important to suppress noise or see sharp features. Going from the top of the table to the bottom, the sharpness decreases, while the noise suppression increases. Since all interferograms are saved, the apodization can be changed on data in memory or on stored files, and the spectrum recomputed. If this setting is changed, an automatic recalculation of all relevant spectra will be performed.

Temperatures is where the instrument and blackbody temperatures are set, and their respective controllers can be turned on and off manually. When this item is selected, a dialog box is displayed. At the top of this box, there are 3 entries for blackbody set points, all in degrees C. The topmost entry (Manual BB Set Point) is for manual control of the D&P blackbody from this screen. After setting a temperature here, the blackbody must be turned on, using the BB on/off control at the bottom of this dialog box. The next two entries (AutoCalibrate Cold BB and AutoCalibrate Warm BB) are for the Cold and Warm set points for the blackbody in the automatic calibration sequence, which is explained under the Process menu description, under the Calibrate function. These are the

set points that will be used in the calibration sequence of cold, then warm blackbody. They are entered here to avoid having to specify them each time a calibration is done.

Below the 3 blackbody set points is the Instrument Set Point. This is the set point for the instrument temperature controller. It is initially set at the current instrument temperature when the system is turned on. It may be reset manually at any time. To change any of these set points, use the mouse or Tab keys to select it, and type the new value, followed by Enter. The new value should appear in place of the old.

Below the set points are two on/off controls. One is for instrument control, the other for manual blackbody (BB) control. The current state of each control has the dot filled in. The initial settings are Instrument control ON, Blackbody control OFF. To change these, use the mouse, or use the Tab key to select the control, then the cursor key to change it to a new setting. All new settings will take effect when Enter is pressed, or the OK button is activated. Selecting Cancel will reload the previous settings.

Display Menu

The Display menu has 4 items in its submenu, selected by mouse, arrow key, or underlined letter. They are:

Plot Type   Axis Units   Plot Scales   Time Resolved Display

Menu Selections

Plot Type specifies what type of display to use for data. The choices are:

Interferogram   displays the interferogram full screen in one window
Spectrum   displays the spectrum full screen in one window
Both   displays the interferogram in one window at the top of the screen, and
                                  the spectrum in a separate window at the bottom of the screen.

Selecting this item brings up a dialog box with three choices. The current selection will be marked with a dot. To change the plot type, use the mouse to click on it, or cursor keys plus Enter to select a new setting. The submenu closes, and the existing data will be re-plotted. If there is no data, no re-plot will be done. When running in the 2X2+1 display mode (via the <alt>F8 key), the Both option is not available.

Axis Units is used to set the X and Y axis units for all displays. There are three choices for the X units:

Micrometers   The X scale is displayed and exported in micrometers (um)
Nanometers   The X scale is displayed and exported in nanometers (nm)
Wavenumbers   The X scale is displayed and exported in wavenumbers (cm^{-1})

It should be noted that the X, or wavelength, scale is not linear, i.e. having unequal delta X values. Any plot or further processing of ASCII exported data should use the wavelength scale included in the exported X, Y data.

The Y units are those for raw data only. Processed data is either dimensionless or expressed in calibrated units of physical properties. At present, there is only one choice for raw data units:

Volts per FFT component   The Y scale is detector volts per spectral element.

The currently selected units for each axis are marked with a dot. To change units, click on the new setting with the mouse, or use the arrow keys or Tab to highlight the new choice. The dot will indicate the new selection. Then choose OK to finish the process, and the new scales will take effect. Choose Cancel to leave without changing the units.

Display Scales is used to set the display limits for interferogram and spectral plots. When this item is activated, a dialog box appears to select Spectrum or Interferogram scales to set.

Choosing one of these brings up another dialog box containing settings for the X scale and Y scale. For the X scale, a low and high limit can be set, or there is a choice for All X points to be displayed. These are mutually exclusive choices. When displaying a plot, the F8 function key can be used to toggle between All X and the manual limits set here.

For the Y scale, a low and high limit can be set, or Auto scaling. These, too, are mutually exclusive choices. When displaying a plot, the F9 function key can be used to toggle between Y-axis auto scaling and the manual limits set here. Once the limits are set up, choosing OK sets the new limits, or Cancel leaves them unchanged. It should be noted here that the manual scale settings are altered when using the cursor arrow keys to zoom and pan on a plot being displayed. To get back to specific manual scale settings, this screen will have to be used.

The Y scale for spectral plots has separate settings for raw Spectral data, Math functions, Radiance, and Emissivity. This facilitates looking at various types of data without having to constantly adjust plot scales.

Time Resolved Display is used to view a user-specified number of coadds within a single data file of many coadds. Any number of coadds from 1 to the total number in the file can be specified. This allows data in a file to be viewed at the highest possible time resolution. A dialog box appears where the number of coadds to be used in viewing is set. Selecting OK then brings up a File Dialog Box, which is used to find and specify the desired file to be viewed. Once this is selected, the plot appears with a FileName of C:\TRM\TRM_0000.sam . This is a temporary file created in the C:\TRM directory for this function only, and all data in this directory, and the directory itself, is deleted after the program exits. Pressing the + key will sequence forward in the file by the number of coadds specified, and the – key is used to move backward. Using Ctl with the + or – key will move 10 coadds at a time, and using the Alt key with + or – will move 100 coadds at a time. The Ctl and Alt keys with the + or – key will move 1000 coadds at a time. This allows rapid movement through large coadds of up to 10,000 spectra and at 1 coadd at a time.

Process Menu

The Process menu normally has 2 items in its submenu, selected by mouse, arrow key, or underlined letter. Once a sample has been calibrated, a third item to fit a Planck function to a calibrated radiance appears. If a Planck function has been fitted to a calibrated radiance, a fourth menu item appears to remove the Planck function. The four functions are:

Math   Calibrate Instrument   (Fit Planck to Radiance)   (Remove Planck Plot)

Menu Selections

Math is used to set which math, if any, is to be done on acquired or restored data files. The choice of Math function also determines what types of data will be acquired or restored when any of those functions are used. When the Math item is selected, a dialog box appears with a choice of None, 5 different simple math operations, or Radiance and Emissivity. They are:

None   no math performed, raw data displayed

Ratio   Sam/Ref   the Sample file is divided by the Reference file
Difference   Sam-Ref   the Reference file is subtracted from the Sample file
Difference   Ref-Sam   the Sample file is subtracted from the Reference file
Inverse   1-Sam/Ref   the ratio function is subtracted from 1
Absorbance   -log (Sam/Ref)   the logarithm of the ratio is calculated and negated

Radiance   f (cbb,wbb,sam)   blackbodies are used to calibrate a sample file
Emissivity   f (cbb,wbb,dwr,sam)   a calibrated radiance is corrected for sky reflected
                                     energy and divided by a Planck at the estimated sample
                                     temperature

The current math function being used will be indicated with a filled in dot when the Math function is selected. To change the function, type the underlined character, click on the new one with the mouse, or arrow to it and press Enter. The menu will close, and, if the data is available, the plot with the new function will be calculated and displayed. To leave the Math function without changing anything, press ESC or Cancel. The 5 simple math functions can be done on calibrated spectra by checking the "Calibrated Spectra" box on this screen. Un-checking the box will perform math on raw data files.

Calibrate Instrument appears under the Process menu. This operation requires two blackbody data files (a Cold and a Warm) to be acquired or restored from disk. The calibration function generates a slope and offset correction at each wavelength, which is then used to take out the instrument function normally seen in the raw data. The units of Radiance will be in [**Watts/m^2*um*sr**]. The generation or regeneration of these corrections takes place automatically whenever any blackbody is acquired or restored. At least one Cold and one Warm blackbody are needed for a valid calibration. As soon as one of each is loaded, the calibration function is generated. This is indicated by the "Instrument Calibrated" message in the lower left part of the status line at the bottom of the screen. Subsequent acquisition or restoring of any blackbody data will automatically trigger a re-calibration to occur. The calibration will be valid even if other math functions are selected and other types of data collected.

Selecting this menu item brings up a submenu with three choices:

Acquire Data and Calibrate   to acquire new BB data
Open BB Files and Calibrate   to restore previously acquired BB data
Set Temperature of External BB   to use a non-D&P external BB

Selecting the first option, **Acquire Data and Calibrate**, will open a dialog box for the Autocalibrate function. From this screen, the instrument's blackbody can be controlled, data acquired, and instrument calibration performed. There are 5 choices on this screen:

Set Cold BB	selects the cold setting for blackbody, highlighted if selected
Set Warm BB	selects the warm setting for blackbody, highlighted if selected
Acquire	acquires the cold or warm blackbody data when at temperature
BB Off	used to turn the blackbody controller off after collecting data
Close(X)	closes the Autocalibrate screen

The **Set Cold BB** and **Set Warm BB** choices each have the current set point for each printed underneath the selection box. These are preset by the user under the Instrument-Temperature menu item. The **Acquire** box has a note under it as to the current state of the BB control. It will indicate whether the BB control is Off, or display the set point when Cold or Warm is selected. **BB Off** is used to manually turn off the blackbody after all data has been collected. The instrument calibration will be updated automatically after a new BB file is loaded or acquired, even if the Math function is changed.

Once the choice of cold or warm blackbody has been made, the blackbody will be turned on and start slewing to the set point. It may take a few minutes for the blackbody to reach the set point. The actual blackbody temperature is indicated on the status display at the bottom of the screen as "Tbb". When it has stabilized at the new set point, the acquisition can be started. Activating the **Acquire** function brings up a second dialog box for the actual acquisition of the data. The instrument will acquire the number of coadds presently set, then prompt for the data to be saved or not. Saving will bring up the File Dialog box, described under the File Menu description. After that, control returns back to the Autocalibrate screen. From there, blackbody data can be taken or re-taken, the blackbody turned off, or the Autocalibrate screen can be closed.

Selecting the second option, **Open BB Files and Calibrate**, will open the File Dialog box, which is described under the File Menu description. Using the File Dialog box, choices are made for a stored Cold, then Warm blackbody files. These are loaded into memory one at time and displayed, the instrument is re-calibrated, and the menu closed. The display will show the Warm blackbody spectrum.

Selecting the third option, **Set Temperature of External BB**, will open a dialog box for the External BB function. This function allows the use of an external blackbody calibrator to replace the D&P supplied blackbody. The temperature of the external blackbody can be typed into the dialog box, then it should be designated as either a Cold Black Body or Warm Black Body. Once OK is selected, the data will acquired. It can also be stored just like any other file. The same data will be placed in memory, and used as the current calibration data.

(**Fit Planck to Radiance**) appears under the Process menu only if three operations have been performed:

The Math function is set to Radiance
The instrument has been calibrated with Cold and Warm blackbodies
A sample has been acquired or restored

This function is used to fit a Planck function to a Calibrated Radiance spectrum. Once selected, a dialog box appears to set the temperature to be used for the Planck. There are two choices for setting the Planck temperature:

Manual-Input Planck Temperature   allows user to set Planck temperature manually
Auto-Fit Planck Temperature   fits the Planck to the Calibrated Radiance

For the manual input, a dialog box appears where a Planck temperature can be entered in degrees C as XX.X. A temperature can be typed into the prompt on the screen, followed by Enter. Activating the Compute function computes the Planck at the specified temperature and overlays it on the Calibrated Radiance spectrum. For this computation, the Planck emissivity is set to 1.0. The current Planck temperature is displayed in the upper left corner of the screen when this function is active. The Cancel box terminates the Planck Fit function.

The Auto-Fit function brings up a dialog box in which a wavelength interval, and a known emissivity value within that interval, can be specified. To continue, the lower and upper wavelengths of the interval are entered in their respective blocks, each followed by the Tab key. The Emissivity Value in that interval is typed into its box. Selecting Compute will then try to match the Planck function to the present Calibrated Radiance, in the interval specified. That Planck will be overlaid on the Calibrated sample radiance to show how good the fit is. This can be performed repeatedly and alternately with the manual fit to optimize the Planck fit to the Calibrated Radiance spectrum. The final Planck temperature will be used in the Emissivity calculation. The current Planck temperature is displayed in the upper left corner of the screen when this function is active. The Cancel box, again, terminates the Planck Fit function.

(**Remove Planck Plot)** is present on the process menu when a Planck function has been fit to a calibrated radiance curve. Activating this function will remove the fitted Planck and display the underlying calibrated radiance again.

Help Menu

The help menu has 1 option in its submenu, selected by mouse, arrow key, or underlined letter. They are:

About   displays the current software revision level.

Function Keys

The function keys are linked to frequently used operations. There are 10 function key assignments listed across the top of the screen, just below the menu bar. Their assignments are:

F1-Acquire   starts the acquisition of a data set
F2-Open   brings up the File Dialog box to open a file (same as menu File-Open)
F3-Save As   brings up the File Dialog box to save a file (same as menu File-Save As)
F4-Refresh   used to refresh the screen after making changes
F5-Export   used to start the ASCII File export process (spectra only)
F6-Run   run without saving data
F7-Cursor   puts a cursor on interferogram or spectral plots

F8-X Scale   toggles the X scale between ALL X and USER X scales
F9-Y Scale   toggles the Y scale between AUTO Y and USER Y scales
F10-Status   brings up a status screen showing currently loaded files
F11-View   toggle between viewing and data acquisition (auto BB only) [1]
<alt>F5   Show mirror step number in information bar at bottom of window [1]
<alt>F8   Diagnostic 2X2+1 Display
<Alt>F9   turn off audible temperature alarm
<Alt>F10   Factory Setup, used to set up instrument operating parameters

(1) Auto blackbody systems only

F1-Acquire starts the data acquisition process for the spectrometer.

The first dialog box is used to select a data type to acquire. The first two selections are always for SAM type data, either a Single file or Continuous Acquisition of sequential files. The Continuous Acquisition mode is used in conjunction with the AutoName function to make long data collections, up to 1,000,000 files. Each file will contain the number of coadds currently set. The continuous acquisition is stopped by hitting F1 again, or ESC. This long sequence can be reviewed later by opening one file in the sequence, then using the +/- (1 file at a time) or **<Ctl> +/-** (10 files at a time) keys to move forward or backward in the file sequence.

The other acquisition file type choices depend on which Math is selected under **Process-Math**. For math functions requiring one or two spectra, the other choice will be Reference. For Radiance math, Cold Blackbody (CBB) and Warm Blackbody (WBB), are offered as other choices. For Emissivity math, the Downwelling Radiance (DWR) selection is added to those of Radiance. Once a file type/acquisition mode is selected, data will be acquired.

For a Single SAM, or any other file type other than Continuous, the number of coadds set under the Instrument-Coadd menu item are acquired and averaged. The final averaged spectra is displayed on the screen after it is acquired, with whatever math is set. The display will be the plot type set under the Display-Plot Type menu (Interferogram, Spectrum, or Both). After the data has been acquired, a prompt appears to Save or Cancel. If Cancel is chosen, the data will be in memory only, but not on disk. If Save is selected and Autoname is enabled, a prompt for annotation only will appear, and the data will be saved with the next sequential filename, using the appropriate file extension for the data type chosen. If Save is selected and Autoname is disabled, a prompt for annotation will appear, and then the File Dialog Box for File-Save appears with the appropriate file extension for the data type chosen. A name can then be entered in the File name section, with no extension. Alternatively, an existing file can be replaced with the current data by highlighting the name of the existing file, and selecting OK (a prompt to "Overwrite Y/N" will appear). The file is then saved into the currently selected directory, under the specified name, with the appropriate file extension. A full screen plot will then be updated, with the last acquired interferogram and/or the coadded spectrum displayed.

If Emissivity mode is active under Process-Math, a prompt will appear each time down-welling radiance data (.DWR) is acquired. The temperature and emissivity of the diffuse plate used to measure the down-welling radiance must be entered. This is needed to compute the emission from the plate and subtract it off the measurement, leaving only the reflected down-welling radiance. The gold diffuse plate supplied as an accessory typically has an emissivity of about .03-.04. Also, when any new data is acquired in Emissivity mode, a prompt for the Planck fitting method will appear after the new data is acquired. Either the manual or auto fit can be specified. (See description under Process-Fit Planck to Radiance).

For Continuous Acquisition of SAM files, a prompt for file annotation will appear first. Once that is entered, the continuous acquisition will commence, and continue until either F1 or ESC is pressed. This mode can be restarted by hitting F1 again, and selecting Continuous Acquisition. The file number sequence will pick up where it left off. It should be noted that maximum speed (i.e., minimum time between files) will be achieved by minimizing the data displayed on the screen, since this takes time away from the acquisition, processing, and storage of data. By choosing Spectrum only, and limiting the wavelength range to a small increment, such as 2 microns, will minimize the time between files. This is especially important in high speed (e.g. 100 spectra per second) instruments.

F2-Open is a shortcut for the File-Open menu item. See the description under the File menu section.

F3-Save As is a shortcut for the File-Save menu item. See the description under the File menu section.

F4-Refresh will recalculate and redisplay a plot at any time

F5-Export will generate an ASCII text file or .SPC file of a spectrum being displayed on screen. When it is activated, a dialog box appears to select which type of file to export.

If SPC is selected, the next screen is the File-Save dialog box. After setting a folder and file name to save under, the SPC file is written out. The SPC file contains the wavelength and intensity data over the entire acquired range, not just the displayed portion as in the ASCII format file

If ASCII is selected, a dialog box appears to set the range of wavelengths to export. The beginning and ending wavelength is entered in whatever units are being used. Selecting OK will bring up a plot of the specified region to be exported. A dialog box appears in the middle of the plot area on the screen, asking "Export This?", with YES, NO, and QUIT options. If the region is incorrect, activating the NO box will bring up the dialog box for entering the wavelength range again. If it is correct and Autoname is enabled, selecting YES will save the ASCII file with the next sequential filename, and the appropriate file extension, as per the list for ASCII files under Software Operation. The filename used will be displayed on screen. ESC removes it. If the region is correct and Autoname is not enabled, the File Dialog Box for File-Save appears with the appropriate file extension for the ASCII data type being displayed. A name can then be entered in the File name section of the File Dialog Box, with no extension. Alternatively, an existing file can be replaced with the current data by TABing to the section containing the file list, highlighting the name of the existing file, and selecting OK (a prompt to "Overwrite Y/N" will appear). The file is then saved into the currently selected directory, under the specified name, with the appropriate file extension. A full screen plot will then be updated, with the last acquired interferogram and/or the coadded spectrum displayed. Selecting QUIT terminates the ASCII export function.

The Time Resolved Output option for export will generate a CSV type ASCII data file for any SAM type file. There will be some header information, followed by data. The first row of the data will be the wavelength scale for all the data. Each row after that will be a spectrum of each individual spectrum in that file. For very large coadds, this can be a huge amount of data. The import into Excel will be limited to 256 columns, so the wavelength range should be adjusted for less data points than that. Zero filling will also affect the number of data points.

F6-Run will activate continuous data acquisition and updating without saving data. The current settings for coadds, resolution, zero fill, and apodization will be used. The current math will be computed, and the scales for that math function will be used. This is a toggle function key, or ESC will also terminate it. This is a good way to observe the effects of outside measurements in real time if it is not desired to save the data. Any math function selected will display results in real time.

F7-Cursor puts a crosshair cursor on a plot of interferogram or spectrum. Values at the cursor are read out in the top left of the screen. If both interferogram and spectrum are displayed, the cursor will be on the spectrum plot. This is a toggle function; pressing it once displays the cursor, pressing it again takes the cursor off the plot.

F8-(X Scale) is used to toggle between the User-X and All-X scales for the horizontal range to be displayed in a plot. The User scales are set in the Display-Scales menu, and are also affected by zooming and panning with the cursor keys. All-X will display the entire range of X points. This means all data points for an interferogram, and all spectral points between ½ the reference wavelength and 25 microns.

F9-(Y Scale) is used to toggle between the User-Y and Auto-Y scales for the vertical range to be displayed in a plot. The User scales are set in the Display-Scales menu, and are also affected by zooming and panning with the cursor keys. Auto-Y will automatically fit the plot to the nearest whole units.

F10-Status brings up an overlay on the screen that shows the operating parameters and all currently loaded data for whatever math function is selected, and whether they are "Active". The operating parameters displayed at the bottom of the screen include Coadds, Resolution, Zero Fill, and Apodization.

The left side of the upper part of the overlay lists the data types required for the current math function. Next to each data type is the word "Active" if it is presently loaded. Just below it is the currently loaded file name. If nothing has been loaded for a data type, then the word "Active" will not appear, and no file name will be listed. If data has been acquired, but not stored, "Active will appear, and the "File Name" will be "XXXX in memory", where XXXX is the data type (e.g. Sample, Reference, etc.). If the data acquired has been saved, or has been restored from disk, the "File Name", with path, of that data file will be shown, and "Active" will appear. Esc or OK will exit the Status screen.

F11-View (optional) is used on systems with an automatic blackbody accessory to put the fore-optics in and out of viewing position. Since this is driven by a stepper motor instead of a lever, the user cannot move it manually. This is a toggle function that returns the mirror to the parked position that allows data to be taken.

<Alt>F5 turns the display for motor step position on and off on systems with an automatic blackbody. This is generally provided with the 4" fore-optics. It is a toggle function.

<Alt>F8 is used to toggle between the normal display of interferogram and/or spectrum, and a diagnostic 2X2+1 display, which shows each of the 4 interferograms or spectra per revolution. Only one or the other can be displayed in 2X2+1. The normal display shows the average of the

number of coadds selected. The 2X2+1 displays the spectral averages of each of the 4 spectra in the 2X2 area. The +1 area is the total average, or the 0 degree interferogram.

<Alt>F9 will turn off the audible temperature alarm if the Ambient temperature exceeds the limits set in the Factory Setup screen

<Alt>F10 brings up the Factory Setup screen. From this screen, all instrument basic operating parameters can be set. Normally, these are not accessed by the user. **Some of these settings can cause erroneous data to be collected. The user should be very careful about changing any without contacting the factory!!**

The parameters are :

Dispersion Coefficients	Xm, Xb, Xc
Spectrometer Model	102, 202, 402, etc.
Data Points to be Acquired	Number Points
Laser (microns)	Reference Wavelength
Ambient Temperature Alarm Limits	Enter temperatures (deg C)
Instrument Temperature Alarm Limits and Tolerance	Enter temperatures (deg C)
Motor Steps to BB, View, Clear positions	Enter # steps from Home[1]
Display Size	Adjust to fit to screen

(1) only on systems with automatic blackbody

Dispersion Coefficients

The dispersion coefficients are used in the instrument dispersion correction. These values are determined by the type of optics used in the interferometer. There is a value for Offset (Xc), LogSlope (Xm), and LogOffset (Xb) in the equation:

X offset (cm^{-1}) = Offset (Xc) + 10^(LogSlope (Xm)*X + LogOffset (Xb)).

This is calculated for each value of X (in cm^{-1}) from the raw FFT, and added on to each value to generate a corrected wavelength scale. These do not require any adjustment under normal circumstances.

Spectrometer Model

Spectrometer Model is where the instrument model number is stored. Certain software options are determined by the Spectrometer Model setting. The TurboFT Model is: 202.

Data Points to be Acquired

The Data Points to be Acquired. The number of data points is determined by the scan angle of the interferometer, sampling frequency, resolution, and length of the Data Gate in the electronics. This must be a multiple of 1024. For 4 cm-1 resolution, the proper setting is 4096. For 8 cm-1 resolution, the proper setting is 2048.

Laser(microns)

The reference Laser Wavelength determines the absolute accuracy of the wavelength scale. When laser diodes are used, each one has a slightly different wavelength, which is set here. This value is set at the factory, and does not normally require adjustment.

Ambient Temperature Alarm Limits

Limits to be used for setting off an over/under temperature alarm. 10 to 40 degrees recommended.

Instrument Temperature Alarm Limits

Limits to be used for setting off an over/under temperature alarm. 15 to 35 degrees recommended, with a 5 degree tolerance.

Motor Steps (optional)

This setting is only for systems with an automatic blackbody. Three entries are required here: number of steps to BB position, number of steps to View position, and number of steps to Clear position. All steps are measured from the Home position.

Display Size

This is a scroll adjustment to fit the D&P screen to different computer screen resolutions and sizes. Move the scroll left (smaller) or right (larger) until the D&P screen just fills the computer screen.

2X Oversampling (optional)

If checked, this box changes the choices for resolution to ½ of the normal selections for a given number of data points to acquire. Its meaning is that, instead of acquiring twice the path length over the angle of rotation, the sampling frequency has been doubled, thus oversampling a lower resolution scan.

Measuring Emissivity

The instrument has specialized software for the measurement of surface emissivity of targets in the field. For this, four raw data files are required; three are for calibration and one is the sample itself. Of the three calibration measurements, two are blackbodies and one is a measurement of down-welling radiance. The blackbodies are used to calibrate both the sample and the down-welling radiance spectra. The down-welling radiance data is collected from a diffuse reflector placed in the field of view of the instrument. Samples are then placed in the same location as the diffuse reflector when they are measured. In this way, the reflected down-welling radiation off the target samples can be subtracted out to give the absolute emissivity.

The algorithm used to compute the emissivity is given by:

$e_s(l) = [L_s(l)-L_{dwr}(l)]/[B(l,Ts)-L_{dwr}(l)]$; where

$e_s(l)$ is the surface emissivity of the sample as a function of wavelength;

$L_s(l)$ is the calibrated radiance of the sample;

$L_{dwr}(l)$ is the calibrated radiance of the downwelling radiance;

$B(l, Ts)$ is a Planck function at the sample temperature.

The down-welling radiance term must be corrected for the emissivity of the diffuse reflector and its temperature. These two parameters are prompted for as part of the data acquisition process for a down-welling radiance file. The sample temperature is derived by fitting a Planck function to the calibrated sample radiance. Two methods are provided in the software for doing this; a manual fit or an automatic fit. See the description under Process-Fit Planck to Radiance. The manual function simply inputs a temperature, computes the Planck, and overlays it on the sample radiance curve. The temperature can be adjusted for a good visual fit. The automatic method requires knowledge of a spectral region of the sample radiance with a known emissivity. The interval from 7 to 7.5, with an emissivity of 1.0, is generally good for most samples. The automatic function allows the interval start and end points, and the known emissivity in that interval, to be entered. The Planck function is then fit to the sample radiance in that interval by a least square error algorithm, and overlaid on the sample radiance to see the quality of the fit. The temperature of that Planck function is displayed in the lower right corner of the status area of the screen.

When the Planck function at the proper temperature is found, this is used in the computation and display of the final emissivity curve. In emissivity mode, a prompt is presented to select a method of Planck generation whenever a new file is acquired or restored. Either the manual or automatic function can be specified. The manual function will ask for a sample temperature, while the automatic function will ask for a wavelength interval and emissivity value in that interval. After inputting the values, a new emissivity plot will be generated and displayed.

It should be noted here that emissivity is best measured outside, where there is less downwelling radiance. If measured inside, the downwelling radiance can swamp out the sample radiance unless the sample is heated above room temperature.

Getting Data Off

Any of the standard PC functions can be used to get data off the Turbo FT. This includes USB memory stick or "thumb drive", built-in CD/DVD writer, or Ethernet connection. Use Windows Explore to select the desired files and move them to the desired device.

Shipping Procedure

The D&P Instruments Turbo FTIR Field Emission Spectrometer requires special handling during shipment. There are optical and electronic parts inside which can become dislodged if a sharp blow is transmitted from outside the box. The computer generally has its own carry case, which holds most cables and accessories. The sensor head requires special treatment.

Our standard method of shipping the sensor head is to first place it into a plastic bag for moisture protection. Then, it gets packed by itself into a medium sized box full of Styrofoam peanuts. This box is then packed into another, larger box, also full of Styrofoam peanuts. The instrument itself is about 12"X8"X8". The medium sized box for it should be at least 4" larger on all sides, or 20"X16"X16", filled in on all sides with Styrofoam peanuts. The outside box should be much larger, minimum 30"X24"X24", and also filled with Styrofoam peanuts. The Styrofoam peanuts provide the best shock absorption of any packing material. We have shipped this way to many customers, including overseas, and have never had a problem. As an aside, both solid foam

and bubble wrap transmit shock quite well from the outside of the box, and thus are <u>not</u> recommended.

In addition to packing this way, we always insure each package for a minimum of $10,000. This would not only make it somewhat easier to recover losses from damages that might occur, but sometimes gives the package special treatment by the carrier. We have observed that packages insured for $10,000 and up may be put into separate staging areas at the shipper's depot. They are probably treated carefully all the way to their destination. Some shippers may require inspection of the packing inside the box, but this is a small price to pay for damage liability. In addition to this, there is also some recovery if the parcel is completely lost.

<u>System</u> <u>Specifications</u>

	General	**This System**
Spectral Range:	1.7 to 25 micrometers, maximum	2.0-16 micrometers
Spectral resolution:	4, 8, and 16 cm^{-1}, adjustable.	4, 8 and 16 cm-1
Spectral Accuracy:	+/- 2 cm^{-1} across the spectral range	same
Scan rate:	25-100 spectra per second	100 spectra/second
Sampling frequency:	200 KHz - 1.2 MHz	1.2 MHz
IR Signal filter bandwidth:	64 KHz – 512 KHz	512 KHz
Analog to Digital converter:	16 bits, +/-10 Volts FSR[1]	same
FFT size:	1024 to 32,768 [2]	same
Interferogram size (max)	2048 - 4096 data points	4096 data points
Computer type:	PC compatible, portable	same
Operating system:	Windows XP™	same
Operating temperature range:	15 to 35 degrees C (instrument temperature)	
Sensor Head Size:	12"L X 8"W X 8" H	
Weight:	10 lbs.	
Power:	30 Watts max., 10 Watts typ. [3]	

(1) Full Scale Range
(2) Depends on spectral resolution selected, in conjunction with the Zero Fill function
(3) Maximum power is with all temperature controllers on at the same time, plus the spectrometer.

Troubleshooting

General

If no spectra appear on the screen, check the green LED on the expansion board of the computer. This is located on the same board where the 2 system cables plug in. It should flash on and off if data is being requested by the software, either using F6 (Run), or F1 (Acquire). One possible source of any problem is instrument temperature. The operating temperature range of the interferometer is 15 to 35 degrees C. The instrument temperature is internally controlled, and can be read off the bottom of the computer screen.

If the LED is flashing on and off regularly, check all connections, disconnecting and reconnecting them. This would include the three cables between the computer and sensor head, two cables from the IR detector into the black enclosure, and blackbody and stepper motor cables into the other black enclosure. This should be done with power off.

If the scan works, but no spectra are seen on the screen, it may be that the detector has not been filled properly, or has run out of LN_2. Normally, the detector Dewar lasts for 12 hours from an initial fill. Refer to the Optical Subsystem section for detector filling instructions. Also, the Dewar needs to be re-pumped every few years to maintain its vacuum. The symptom of poor vacuum is shorter hold times and condensation on the outside of the Dewar. Listen for any unusual sounds, such as clunking or chattering.

If the spectra are seen, but do not seem to be proper, check that the lever on the foreoptic eyepiece is pushed down. For the automatic BB on the 4 inch foreoptics, look through the clear viewing port on the side of the telescope mount to see if the input steering mirror is properly parked out of the way. Also, note the min and max values of the interferogram, and their location in the data record. A properly working system should put out +/- 1-2 volts near the center of the data record. The peak values and the spectrum peak should go up a little if a warm hand or blackbody is placed in front of the foreoptics.

The settings for the instrument, including laser wavelength, are loaded at the factory in a file called: C:\tfactory.set. This is a read-only file that must not be modified. A second file, TurboFT.ini is in the same directory as the TurboFT.exe file. The TurboFT.ini contains all the information from the tfactory.set and any user preferences that have been set, such as plot scales and Process/Math. If there is a problem with the TurboFT.ini file, delete this file and start the TurboFT.exe. The tfactory.set file will automatically be read and a new TurboFT.ini file will be generated.

CHECKLIST

Check all four temperatures at the bottom of the screen for the normal range of 15 to 35 C.
Make sure the detector is filled properly.
Check the system LED for proper operation.
Make sure the lever for the viewer or steering mirror on the foreoptics is down.
Delete TurboFT.ini in the C:\TurboFT directory and restart the software.
Look at known good stored data to compare with acquired data.
Listen for unusual noise, or lack of fan noise.

System Computer

The system computer is normally very robust, but can act strangely under extreme heat or cold. Usually the screen will fade or have low contrast under these conditions. If there seems to be problem at any time, (such as "hanging up") a warm boot (CTL-ALT-DEL buttons pressed simultaneously) will bring up the Windows Task Manager. Try to End the Turbo FT task in this window and start the TurboFT program up again.

The computer has its own battery for time and date backup, which should last for 5 years.

If the program ever fails to load, or acts strangely, it may be due to a corrupted file, called TurboFT.ini, in the C:\TurboFT subdirectory. It must be deleted to solve the problem. To do this, exit the program, or reset the computer to the Windows desktop. Using Explore, delete the TurboFT.ini file from the \TurboFT subdirectory.

Please note that all factory setup operating parameters, including laser sampling wavelength under Factory Setup (alt-F10) will need to be restored after deleting the TurboFT.ini file. The accuracy of the wavelength scale depends on the sampling wavelength being correct. In addition, the proper dispersion correction constants and number of points to acquire need to be reset. The proper values for this system are:

Dispersion Offset (Xc) = 0.0
Dispersion LogSlope (Xm) = 0.000172
Dispersion LogOffset (Xb) = 0.993
Spectrometer Model   = 202
Data Points to Acquire= 4096
Laser Wavelength   = _____

A backup CD is provided should it ever become necessary to restore the program to the system computer. Transfer all the CD contents into the C:\TurboFT subdirectory using Windows Explore.

After this is done, the sampling wavelength and other factory setup parameters must be set to the correct values in the Factory Setup (alt-F10) menu. Please see the above instructions under System Computer for the proper values to enter.

The settings for each instrument, including laser wavelength, are loaded at the factory in a file called: C:\tfactory.set. This is a read-only file that must not be modified. A second file, TurboFT.ini is in the same directory as the TurboFT.exe file. The TurboFT.ini file contains all the information from the tfactory.set and any user preferences that have been set, such as plot scales and Process/Math. If there is a problem with the TurboFT.ini file, delete this file and start the TurboFT.exe. The tfactory.set file will automatically be read and a new TurboFT.ini file will be generated. When reloading the files from a backup CD, please copy the tfactory.set file from the CD to the root directory of the C: drive so that the file becomes C:\tfactory.set

CHECKLIST

Check for proper parameters under Factory Setup <alt>F10 screen.
Operating temperature of the computer is 15 to 35 C, which is greater than the instrument range.
Delete the TurboFT.ini file in the C:\TurboFT directory, then re-enter factory setup parameters.
Restore the program from the backup CD, then re-enter the factory setup parameters.

If none of the above solves the problem, then contact D&P Instruments in CT at:

(860) 658-0458 Phone/Msgs or (860) 651-0698 FAX
e-mail: info@dpinstruments.com or microfts@aol.com.

It helps to have some diagnostic information when calling, as it is easier to diagnose problems with some data on problem history and present indicators. In addition, looking at old stored data may help in pointing out differences over time in spectral performance. Also note whether any changes have been implemented lately, such as Operating System upgrade, anti-virus upgrade, or any user-installed software.

General Tips for using the Turbo FT Spectrometer

General

The instrument temperature controller has a much easier time heating the instrument than cooling it. Consequently, when working outside, the best results are obtained by setting the instrument temperature to near the highest temperature expected for the day, then letting the instrument equilibrate at that temperature for at least one hour (overnight is better). This will achieve the dual goals of using the least amount of power, and maintaining the most accurate calibration. This temperature can be maintained on the way to the measurement site if power is available. Note that setting the instrument temperature more than 5 degrees above or below its current temperature will trigger a temperature alarm (see manual). This 5 degree limit may be exceeded during a pre-heating operation, but only when the set point is higher than the current temperature, and even then not by more than 10 degrees C. Cooling requires more power than heating, and the controller may overheat if the set point is more than 5 degrees C lower than the current temperature. Therefore, violating the 5 degree limit on the low side is not recommended.

Make sure to allow sufficient time after powering up the spectrometer for the laser diode reference to reach its set temperature, which is usually about 25 degrees C. The farther the temperature is from 25 C, the longer it may take to reach the set point. Generally, again, it takes less time to heat than to cool. Monitor the laser diode temperature on the screen.

It is always advisable to run the instrument a few times at the beginning of a session to warm up the interferometer and drive motor. A few minutes of the F6 continuous running should be enough.

It is best to turn off the blackbody when not in use, as it dissipates power unnecessarily.

Emissivity Measurement

Make emissivity measurements on clear days with little or no cloud cover. This will give the most accurate results because the down-welling radiance will not change much when samples are measured. If this is not possible, take frequent down-welling radiance data, and use the closest one in time to each sample. Also, take blackbodies more frequently at the beginning of a measurement

session, when the instrument calibration may be changing more. After an hour or so, less frequent blackbodies should be sufficient.

When making emissivity measurements, make sure that there are the same objects, including people, near the instrument's field of view for all sample and down-welling measurements. It is best to have no objects around the sample area, and to step away from the instrument about 6-8 feet or so while acquiring data. There is a delay before data acquisition, and a beep will sound after data acquisition is complete. This allows the user time to get away at the beginning, and notifies the user to return at the end of data acquisition. This does not need to be done when acquiring blackbodies, as the instrument is not looking out at the scene.

The sky has a much lower apparent temperature than most samples. For best results in calibrating the down-welling radiance, use a lower temperature cold blackbody, such as 5-10 degrees C. The warm black body should be just above the estimated sample temperature. This is a compromise between obtaining a good sample temperature calibration and a good sky radiance calibration.

Measuring very low emissivity targets may result in erroneous readings. These include targets with low apparent temperatures, such as gas clouds, and highly reflective targets. Diffuse solid targets give the best results.

The sun should generally be on the front side of the instrument, so no shadows are cast on the sample area.

Quick Setup Guide

Once at the measurement site, setup and operation of the TurboFT is quick and simple. Unpack the Sensor Head and mount it onto the tripod. There is a dovetail foot under the base plate of the sensor that slides into the matching dovetail on the tripod head. The proper direction is indicated by an arrow. Slide it in until it is properly balanced, then lock the base plate by turning the lever on the tripod head, just under the sensor base plate.

Unpack the computer and set it near the sensor head. Unless the optional battery powered computer is used, the computer must be connected to AC power to run. The AC cord plugs into the left side of the case. There is also a flat gray cable connector that must be plugged into an expansion card labeled "NI PCI 6259". The connector should be plugged into Connector 0 of that card. Make sure to secure the connector using the thumbscrews on the connector. **This connector should also be disconnected when the computer is stowed for transport.**

Unpack the 3 cables required to run the system. There are two gray cables; one with 9 pin D and one with a 15 pin Hi-density D type connectors. The third is a BNC type.

This is a good time to start filling the detector with LN2. Put in 3-4 funnels first, then let the detector cool down and go through its spouting of vapor as the inside comes to 77K. Then add a little more to fill it to the top.

Connect the 9 and 15 pin cables to the two connectors on the left side of the computer, near the top. They are labeled "SERVO" and "TEMP CNTRL". Use the ends with the threaded posts.

Connect the other end of these cables to the appropriate connectors on the sensor head, also labeled "SERVO" and "TEMP CNTRL". These connectors are on the ends of the two black box enclosures on the sensor head. Use the ends with the latches for the wire clips.

      Connect the BNC cable between the "Det BNC" on the left side of the computer and the "Det BNC" on the underside of the Servo enclosure on the sensor head.

      Attach the telescope mount by sliding it into the black mounting ring on the sensor head. Lock it in place by sliding the locking ring on the viewer tube down into the mating hole in the sensor mounting ring. The 1-inch or 2-inch fore-optics slide onto the end of this mount. For the 4" fore-optics, do not use the telescope mount. The 4" telescope connects directly to the black mounting ring on the sensor head.

      Connect the 1" or 2" blackbody into the "BLACK BODY" connector on the "TEMP CNTRL" enclosure. This connector is polarized, so it only goes in one way. For the 1" fore-optics, the blackbody is connected directly to the end of the tube on the 1" fore-optics. There is a pin that mates with a slot on the blackbody. A slight twist will lock the blackbody onto the fore-optic. This is only placed there during calibration, and can be stored on the round black disk on top of the "TEMP CNTRL" enclosure between calibrations. The 2" blackbody is used identically to the 1" blackbody, and can be stored on the outer black disk on top of the "TEMP CNTRL" enclosure.

      Turn on the computer by depressing the larger round switch on the lower right side of the front panel.

      After Windows loads, double click the TurboFT icon to start the D&P software. During initialization, the instrument temperature controller will be turned on, and the fan on top of the sensor head will turn on. The current temperature of the instrument will be maintained.

      After setting the desired Instrument parameters for coadds, Resolution, Zero Fill, and Apodization, pressing the F6 key will start the acquisition and display, but not save, data. The desired Math function can be selected under Process-Math. If data are to be acquired and saved, use the F1 key, then select the data type. The Single acquisition mode will acquire 1 coadd, then stop. The Continuous Acquisition mode will acquire and store data sequentially until stopped by the user, either by pressing F1 again, or ESC. AutoName must be enabled to save continuously. The software will generate sequential filenames in continuous mode.

      To shut down, exit the D&P software using File-Exit or <alt>X. The current settings can be saved or not. The computer is shut down using the Start menu, selecting Shutdown twice. Windows will shut down the power after it has finished the software shutdown sequence.

Binary File Format

TurboFT Data File Header Version 2.0.2

The format of the TurboFT binary data file is:

Header
Interferogram - as short int's
Interferogram
Interferogram
.
. (repeated for each coadded measurement)
.
Spectrum - as float's

The header is best read using the sizeof(Header) function to determine the size.
The header format declaration in C is as follows:

```
struct H_One {
   char    Label[4];
   int      Version
   int       Revision;
   char    Date[28];
   int       FileFormat;
   char    FileType[4];
   char    OriginalFileName[68];
   char    ReferenceFileName[68];
   char    RelatedFileNameA[68];
   char    RelatedFileNameB[68];
   char    RelatedFileNameC[68];
   char    RelatedFileNameD[68];
   char    Annotate[84];
   char    InstrumentModel[36];
   char    InstrumentSerialNumber[36];
   char    SoftwareVersionNumber[36];
   char    CrystalMaterial[36];
   double    LaserWavelengthMicrons;
   int    LaserNullDoubling;
   int    Padding;
   double    DispersionConstantXc;
   double    DispersionConstantXm;
   double    DispersionConstantXb;
   int    NumChan;
   int    InterferogramSize;
   int    ScanDirection;
   int    ACQUIREMODE;
   int    EMISSIVITY;
```

```
   int    APODIZATION;
   int    ZEROFILL;
   int    RUNTIMEMATH;
   int    FFTSize;
   int    NumberOfCoAdds;
   int    NumberOfIgrams;
   int  SingleSided;
   int  ChanDisplay;
   double    AmbTemperature;
   double    InstTemperature;
   double    WBBTemperature;
   double    CBBTemperature;
   double    Temperature_DWR;
   double    Emissivity_DWR
   double    LaserTemperature
   int        SpareI[10];
   double    SpareF[10];
   char    SpareNA[68],SpareNB[68],SpareNC[68],SpareND[68],SpareNE[68];
   char    End[4];
} Header;
```

Interferogram and Spectrum binary data starts here. Interferogram Integers are 32 bit, Spectrum doubles are 64 bit.

Notes on file format:

The first 12 bytes of the header are used to identify the file type. These should be skipped over.

Note that the DWR Plate Temperature is stored in Header.SpareF[0] and in Temperature_DWR and the DWR Plate Emissivity is stored in Header.SpareF[1] and in Emissivity_DWR.

Note that the Interferogram is InterferogramSize short integers
and the Spectrum depends on the FFTSize*ZEROFILL*512 in floats at the end of the file.

Also note that the wavelength scale must be calculated with the proper dispersion correction.

The binary files do not have a wavelength scale, as our ASCII exports do. The dispersion correction will have to be calculated using data from the header. The correction is an offset, in wavenumbers (cm-1), to the linear scale generated from the FFT. The linear scale from the FFT is given by:

Wavelength Range (cm-1) = (10,000/LaserWavelengthMicrons);
Spectral Range (cm-1) = Wavelength Range/2;
Spectral bin size (cm-1) = Spectral Range/2048; (for full spectral resolution)

Note that LaserWavelengthMicrons is different for each instrument, since the laser diodes are not identical.

The wavenumber scale X(fft) starts at 0 and increases by the spectral bin size to the maximum

Spectral Range

The form of the offset is:

X(corrected)=X(fft) + C + 10 ^ (m*X(fft) + b);

where m is the DispersionConstantXm, b is the DispersionConstantXb of the dispersion correction, C is DispersionConstantXc. These are available both in the header and in the F10 factory setup screen on the system computer.

All of these are stored in the header data.

Reading the data file:

```
int      scan;
int      Nover2;
short int   Isam[Ncoaddsmax][IGRAMSIZE];
float      Ssam[FFTKmax*512];
```


```
// Read the Header
   fread(&Header, sizeof(Header), 1, DataD);

// Read the Interferograms
   for(scan=0; scan<Header.NumberOfCoAdds; scan++)
   {
     fread(Isam[scan], sizeof(short), Header.NumChan*Header.InterferogramSize, DataD);
   }

// Read the Coadded Spectrum
   Nover2 = Header.ZEROFILL*Header.FFTSize*512;
   if(Nover2>FFTKmax*512) Nover2 = FFTKmax*512;    // Limit on Zero Fill
   fread(Ssam, sizeof(float), Header.NumChan*Nover2, DataD);
```