

GHOST 6.75

Multichannel Analyser

USER GUIDE



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1 INTRODUCTION

This guide will give you a quick introduction to the use of *GHOST* v. 6.75. The multichannel analyser *GHOST*, designed around the JRS Fabry-Perot Multipass-Tandem Interferometer, provides an easy way to acquire, save and analyse light spectrum data using an RS-232 communication system to pass the data to a common PC.

We hope you will not encounter any serious problems and that you find this product useful for your research. Follow this guide to learn how to operate *GHOST* and what it can do for you. *GHOST* has been designed to be user-friendly and to require minimal configuration - in any case you should read this short guide entirely before starting to use it.

JRS & the GHOST Team

2 HOW TO GET READY

2.1 Hardware and Software Requirements

GHOST is a lightweight standalone application which should be able to run properly and without performance problems on any reasonably recent personal computer hardware and operating system; in order to run versions 6.75 and higher of the software, we recommend to adopt at least a Microsoft Windows XP™ class workstation, with an available serial (RS-232) or USB port and a serial connection cable. Personal computers equipped with a Pentium III class processor (or better) are advisable. *GHOST* should run also on all the more recent Intel™ and AMD™ processors and on all Windows™ systems versions up to Windows 8, both in the 32bit and 64bit versions.

The application is developed with low-level code, allowing a fair compatibility with older operating systems and hardware; it is however very important that the workstations where *GHOST* is running are kept completely up to date with system updates and patches released by Microsoft. This is particularly true in the case of Windows XP platform, where the operating system was deeply changed through service packs along the years: *GHOST* could not start or crash if the system is not completely updated.

Occasionally, *GHOST* has been successfully tested on linux/Unix OSes, running over Windows emulation software (like the well known package Win-E). In these cases, no particular requirements should be adopted in the environment configuration, providing that the operating system kernel is correctly configured to support RS-232 hardware ports or USB serial emulators.

Versions of *GHOST* prior to 6.75 were also tested to run correctly on PCs equipped at least with an Intel® 486@100MHz processor, Microsoft Windows 95™ and a video card providing at least 256 colours @ 800x600.

We recommend running *GHOST* on a dedicated instrumental machine, or to avoid heavy parallel activity on the same machine when data gathering is in progress. Since the acquisition is run in synchronous mode, some of the spectrum data could be lost if the processor is not quick enough. This problem is quite clear when operating on slower machines: if you run some other program while *GHOST* is acquiring data, you'll probably notice strange figures on the screen. In these cases, your acquisition data will be preserved and wrong signals will be discarded, but it's better you consider this problem.

To take data and synchronisation signals, the PC must be connected to the serial port of the latest version of the JRS Interferometer Control Unit. If you have an earlier version of the control unit (it must have a D-Sub15 socket "Remote" on the rear panel), JRS can provide you with an external update unit. To connect this update unit attach the connectors Remote, TTL out, Trig and Clock to the corresponding connectors on the rear of the control unit. The D-Sub9 connector marked "COM" is the serial port.

The cable you'll use for the connection is a standard one, the same that you would use to connect a modem to your PC, with two small 9-pin plugs. Almost all serial ports on PCs have 9-pin serial ports, but in some old machines you could find 25-pin ones. In these cases you should buy an adapter from your favourite computer shop. It will not be expensive.

The hardware you need on the interferometer side should be provided by JRS, while any standard PC should have a GHOST-compatible serial port or USB. We programmed *GHOST* to recognise any number of serial ports available, so it should work even on computer equipped with multi-serial boards. In case you only have USB ports available (very common on modern hardware), a cheap USB-to-serial adapter can be used to connect the instrument to the PC.

The cable can be connected in one way only, so just plug it into the PC port and the Interferometer control unit dedicated port, or add-on box. It's not important if the PC is running while you do this; we do however recommend that you shut off the interferometer control unit before making or changing any connection.

2.2 Microsoft® Windows™ Port Settings

Before you can install and run *GHOST*, you must ensure Windows™ is configured correctly. The first thing you need to know is the name of the serial port your interferometer is connected to. This should be COM1, COM2 etc. Usually there are only two of these ports installed on a PC, identified on the external chassis near the socket.

The serial port connected to the JRS control unit must be configured to work **at a speed of 57600 bps with no parity check, no data flow control, 8 data bits and 1 stop bit**. The way this can be done changes slightly depending on the operating system used. If you are using a USB to serial adapter, it is possible that this part of the configuration can be performed using specific software provided by the device manufacturer.

The configuration procedure described here refers to all the systems up to Windows 8; the serial port configuration dialogs were only slightly changed across the years..

If you are not sure about the number of the instrument port, configure all available ports with these parameters and you'll be sure this problem is solved.

Windows 95/98

To configure your system, open the “control panel” from the “settings” submenu of the start menu and select the System icon. Select “peripherals management” and then click on the “plus” sign near “ports” (Fig. 1). There will appear a list of the printer ports and serial ports available on your PC. Ignore the printer ports and select the serial port you need to configure; click on the “properties” button on the bottom of the window.

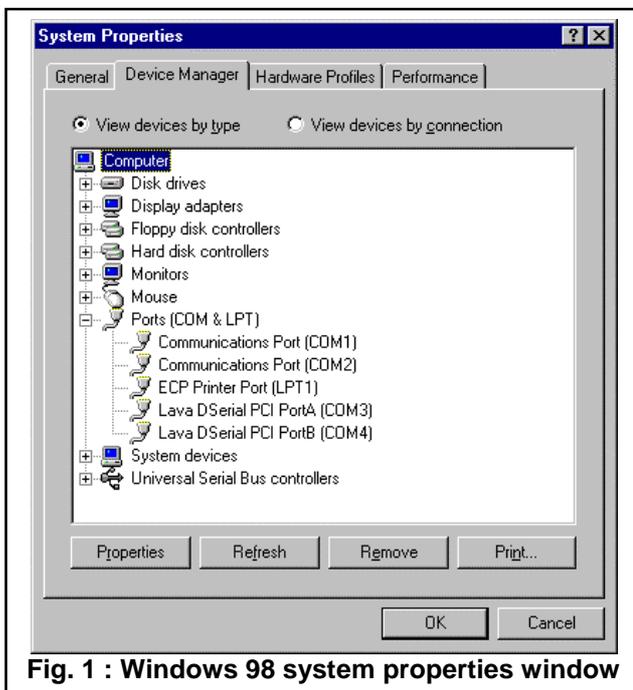


Fig. 1 : Windows 98 system properties window

Click:

Start/Settings/ Control Panel/System/Hardware/Device Manager/Ports (Com + LPT)/Port Settings

The next pop-up window will show some information on the port. Select the “port settings” folder. In the edit boxes you see, you must select a speed of **57600 bps, no parity, no data flow control, 8 data bits and 1 stop bit**. If you click on the “advanced” button you will see the setting for the port buffer. These are not needed in our case, but a large receive buffer could improve performance on a slow system. Clicking OK will change the settings. Once the port is set correctly, these settings will remain unchanged, so you can forget about them. If you have some problem with port opening with *GHOST*, it's a good idea to take a look at the “resources” folder of this window: it could report a hardware problem unrelated to *GHOST*.

Windows XP

On Windows XP systems, the serial ports configuration panel can be reached by opening the Control Panel from the Start menu. Be sure to be logged as privileged user.

While working in the classic view mode (if not already selected, you can switch to classic view by clicking on the “switch to classic view” label in the upper left part of the Control Panel window) the “system” should be listed. When opened, a dialogue for system properties will be shown (Fig. 2). Here, select the “Hardware” folder and the click on the “Device Manager” button.

A new popup will show a list of devices, very similar to that of older systems (Fig. 1). There, expand the “Ports (COM & LPT)”, right-click the port you want to configure and change the parameters. Buffer settings for the serial port can be changed using the “Advanced” button there: a large buffer is normally a good idea and prevents communication problems when the PC is busy.

Windows Vista™, 7 and 8

In these latest Microsoft operating systems, the serial port properties are still accessible through the "system" component of the Control Panel. The window shown in this case is similar to the example shown in Fig. 3.

Once the system properties window is open, it will be possible to select the "device manager" (still similar, in these cases, to the old example in Fig. 1) and find the "ports" section, where any hardware RS-232 port or USB emulated serial port can be configured.



Fig. 2 : Window XP system properties window

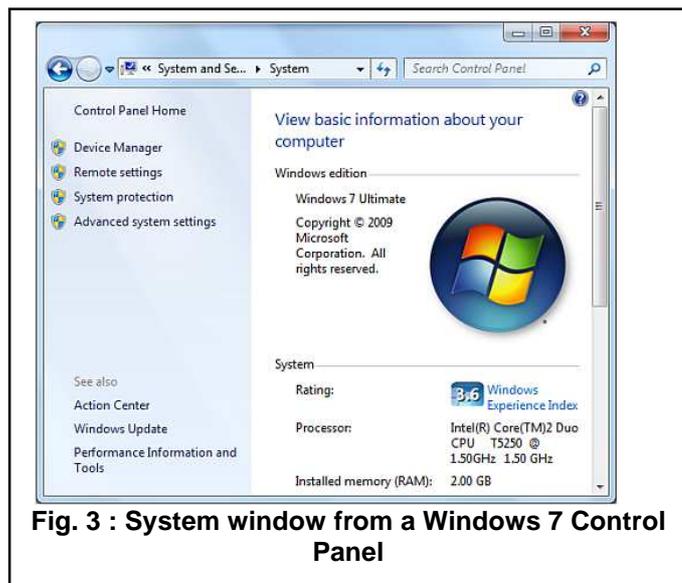


Fig. 3 : System window from a Windows 7 Control Panel

2.3 Program Installation

There is not much to do. You should create a directory on your hard disk (for example C:/ghost) and copy the program executable there.

At the first execution GHOST will ask you for the creation of a "backup" subdirectory where it can store acquisition backups. Backup function is not active by default, however, and the backup directory can be changed to any other location.

If you wish, you can “copy and paste” *GHOST* on your desktop, or create a link to it, or add a command in the menus. We assume you already know how to do it.

2.4 Program Configuration

When the program starts up, you will see the “spectrum window”. We'll talk about this later, now it's time to do some configuration, so simply click the “exit” button on the bottom right. If *GHOST* asks you for confirmation, please answer “yes”.

When the window disappears, you will see *GHOST* main window (Fig. 4). This is a sort of “control panel” that remains active during all program operations and it is used only for configuration purposes. You can see this window even when the “spectrum window” is active; some changes to configuration are possible also while gathering data, such as those in the “visualization setup”. The “exit” button terminates the program, after confirmation, while the “about” button will display some information about *GHOST*.

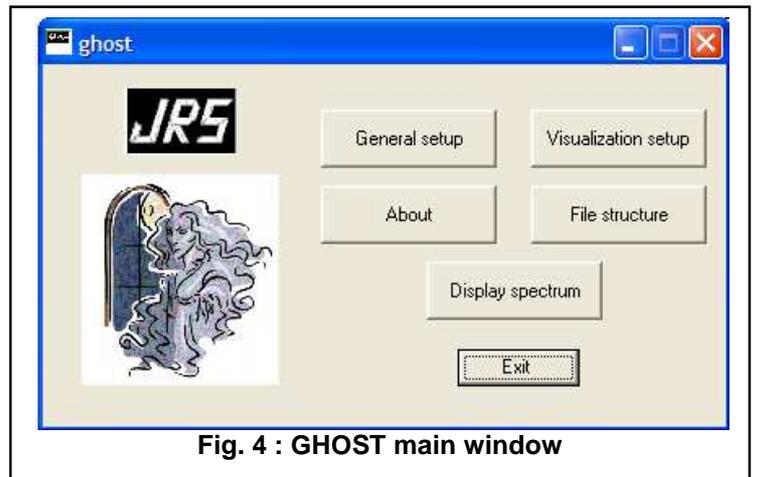


Fig. 4 : GHOST main window

2.4.1 General Parameters

Now, click on the “General set-up” button and look at the window that will appear (Fig. 5). In the list-box, select the serial port you will use. *GHOST* has been programmed to automatically recognise the number and name of any serial port installed.

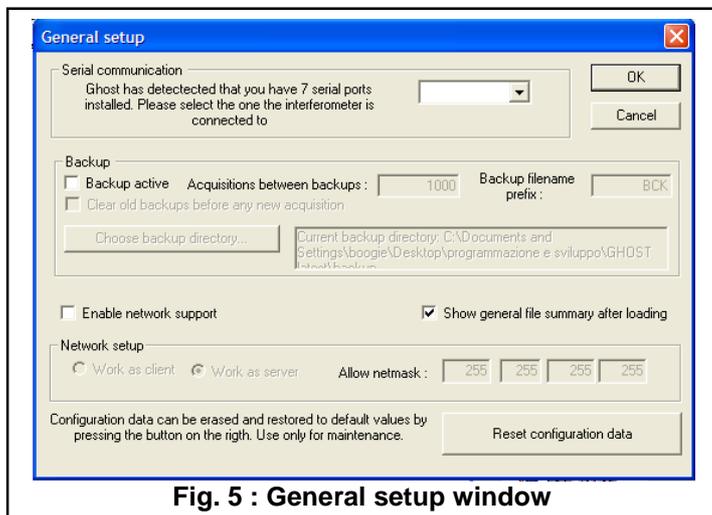


Fig. 5 : General setup window

The body of the window is devoted to backup capability. *GHOST* can do backups during your acquisitions, saving them in a directory of your choice. A backup is simply a spectrum data file that contains data collected from the beginning of acquisition. Just select the backup options you prefer. The “clear old backups” checkbox activates a “dangerous” feature: when you click the “start acquisition” button (in the appropriate window) all the spectrum file backups in the backup directory will be erased. The “backup filename prefix” box contains at most 3 characters that will be prefixed to the backup filename: for example the 1000th backup with BCK prefix will be a file named BCK1000 in the correct directory. By clicking

“choose backup directory” you can select the location of your backups, and even create a new directory, using a standard dialog.

Backups are saved during acquisition, in parallel with it; on slow machines or when system load is high, the backup saving could not be instantaneous and require a second or two, so that the number of cycles performed could not correspond exactly to a multiple of the scan step. This could also happen when you select a very small number of acquisitions between backups.

The next section of the general setup window controls network operations: you can enable this function by checking the appropriate box. If your machine is connected to a network, you could decide to make *GHOST* act as a “server” or a “client”. *GHOST* servers are usually acquisition PCs which are capable of hosting network connections from external workstations: those will be capable of monitoring the signal in real-time and eventually start and stop acquisition or observation. *GHOST* clients are copies of *GHOST* which can connect to a *GHOST* server allowing actions like those described above. We recommend using the same version of *GHOST* on the server and the client case.

In “general setup” window you decide if you want this copy of *GHOST* to act as a client or a server. If you choose the “server” option, you should set the netmask on the right.

For further information, see section 3 of this manual.

At the bottom of the window you can decide if *GHOST* should show the stored comments when you load a spectrum file (show general file summary after loading).

The lower part of the window contains only a button that will reset the program configuration data in the Windows system registry, where they are stored. Just try this option if *GHOST* exhibits unusual behaviour, before calling JRS for assistance. The configuration will be restored to default or blank values: remember to set up again the port after performing the reset.

After the configuration is finished, click OK and return to the main window.

2.4.2 File Structure Parameters

GHOST has been designed to save spectrum data in plain text format and to support 1024, 512 or 256 channels. This means that, when you save a file, you'll get 1024, 512 or 256 lines of data.

At the beginning of each spectrum file, *GHOST* reserves 13 lines for additional information, called comments. Comment lines are ignored as data, but report important information such as mirror spacing, wavelength of incident laser light, the name of the sample and so on. Scan amplitude and scan number are saved in any case (their box is disabled, but checked) on a custom line number. In our experience the default configuration works very well and is suitable for the large part of the users. If you want to customize the file structure, you can do it using the file structure window.

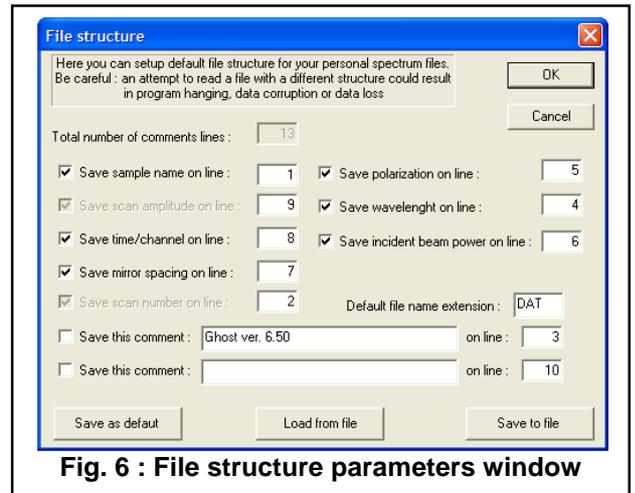


Fig. 6 : File structure parameters window

By clicking on the “file structure” button in the main window you'll see a dialog window containing all the information the user can set up (Fig. 6). In this window you can set what kind of data will be saved and the position in the file (line number). You must ensure that there are no duplicate line numbers and that no line number is zero. *GHOST* will not accept configurations not complying with these rules.

The types of comments available are self-explanatory. The last two lines in the window (where you can read “save the comment”) support the creation of two free comment lines to be saved in any file. If you activate one or both of these, you will get those messages written on the corresponding lines of any spectrum file saved, and those lines will be considered “reserved” for those comments.

This configuration method will allow you to build the file format you prefer, editing only information that you change every time, keeping fixed the other parameters (we'll see later how to do this - paragraph 2.6).

The remaining control options in the configuration window are quite simple. When you first configure file structure, and when you make subsequent changes, remember to click “save as default”, so this configuration will be loaded next time you launch *GHOST*. Another solution is to save the file configuration in a special file using “save to file”. For example if you want to send some data to another user of ghost, which uses a file format different from yours, you should send him your data files together with a file configuration file, so he can load the configuration using the “load from file” button and then read your data files without errors.

Finally, there is a box named “default file extension” that allows you to choose an extension for all your spectrum files.

Please note that it is not a good idea to change file configuration often. We strongly recommend the use of our defaults, changing only free comments and file extension (if needed). GHOST should be able to understand any combination of parameters, but this kind of test is very difficult to perform and GHOST reacts in a quite unpredictable way when data files do not match the current file configuration.

2.4.3 Visualisation Parameters

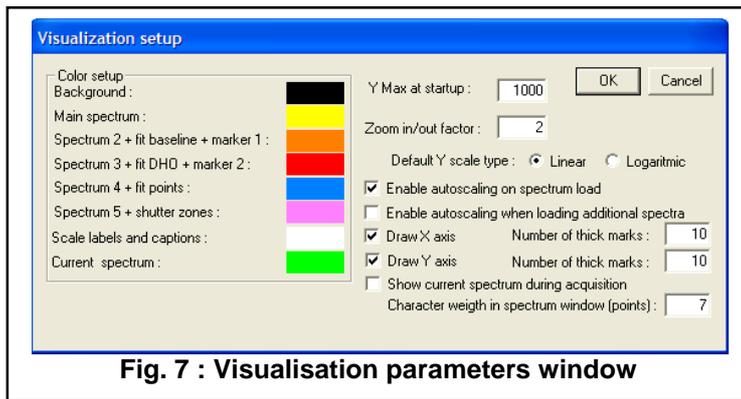


Fig. 7 : Visualisation parameters window

This is a fun section - by clicking on the “visualisation set-up” button of the main window, you will be able to choose the colours *GHOST* uses. In the “visualisation set-up” dialogue (Fig. 7), you will see the colours currently active and other settings. To choose a colour, simply click on the coloured rectangle and you will see a standard colour selection box.

The colours marked as "Spectrum 2", "Spectrum 3" etc. are used in the "multiple viewer" function. The "Current" colour is used to represent data coming from the Interferometer in real time (instantaneous spectrum). Some colours have multiple uses, they are reported for your ease.

On the right you will find some parameters connected with visualisation: *GHOST* represents spectra as number of samples on the Y axis and frequency displacements on the X axis; you can choose if you want axes to be displayed or not and some other parameters. When we apply autoscale on a spectrum, *GHOST* makes a rough estimation of the mean peak intensity and sets a scale appropriately. Remember that you can apply autoscale at any time from spectrum window.

You can apply autoscale automatically when loading a new spectrum, and when loading each new spectrum in the "multiple viewer" window, by activating the corresponding check-boxes.

This window also allows you to select the Y scale limit at start-up and the zoom coefficient. If you want to see the instantaneous spectrum during acquisition, check the last box on the bottom. You can also change the weight of the font used to draw labels in the main spectrum window: this is useful on modern systems, where screen resolution can be high, and the default weight could produce too small characters.

3 PROGRAM CAPABILITIES

3.1 Main Spectrum Window

Now, it's time to discuss *GHOST* features useful for everyday work. Once you finish configuration, you can click the “Display spectrum” button from the main window and begin to use the spectrum window. If you are working on a “network server”, you’ll see immediately a network server dialog (see section 3). After that, the “spectrum window will appear (Fig. 8). You should see the colours as selected and an empty spectrum. Buttons are on the bottom, indicators and edit boxes on the right. On the top of the spectrum image, *GHOST* writes some status data: the current file name, the status of operation (IDLE, ACQUISITION etc.) and other useful information.

The “scale” edit selects the highest value on the Y axis. If you change it, the spectrum will be redrawn immediately. The “cycles” edit displays the number of scans that *GHOST* should do before stopping. You can select an infinite acquisition time by setting this field to 0: the acquisition will run until you stop it manually.

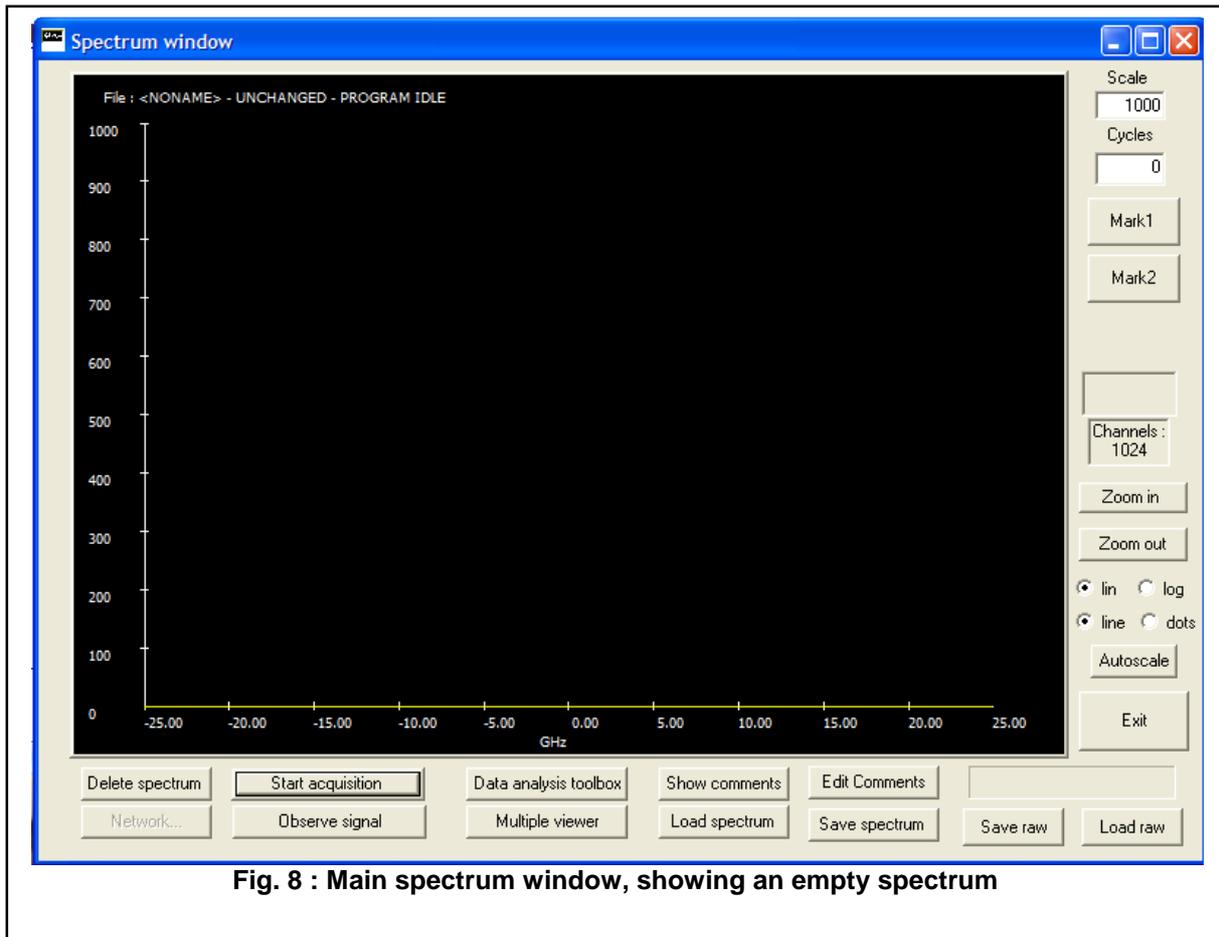


Fig. 8 : Main spectrum window, showing an empty spectrum

Markers can be placed on the spectrum by activating the appropriate push-button and clicking on the image. Marker #1 is controlled by the left mouse pad: marker #2 by the right mouse pad. Once they are active, you can move the markers channel by channel using keys A and D (marker #1), J and L (marker #2). When a marker is active, the text on the marker button will show the frequency corresponding to the selected channel. Two lines of text will be displayed immediately over the marker symbol, showing frequency and counts number of the selected channel. This will allow you to quickly recognize a local maximum in the spectrum or to roughly evaluate line widths. Markers work also during acquisition of data and can be, as well, moved using keyboard or mouse while taking data.

From the radio buttons on the bottom right you can choose logarithmic or linear scale; the spectrum can be displayed as dots or lines; in addition autoscale is available by clicking on the appropriate button. If you apply autoscale to a null spectrum, you'll get a scale limit of 0 and no image on the screen. Other buttons allows you to change scale by zooming in or out, save and load spectrum files.

The most important control is "start acquisition". If you press it, all other buttons will be temporarily disabled and *GHOST* will start gathering data. During acquisition you can still zoom in or out, you can switch between logarithmic or linear visualisation and change directly the scale limit (in this case the scale will be updated after the next acquisition cycle). The display of the acquired spectrum is updated after every cycle, together with the "live" spectrum (if you selected this option). Backups are made automatically as configured.

The progress bar on the right will show you graphically the acquisition time elapsed, while the text line on the spectrum image will show you the time still needed, the channel number and other information.

An acquisition cycle will be rejected only if there is a timing error in the acquisition. A timing error is usually due to software problems (some other program reserving system resources, such as the starting of a screen saver or the opening of an application).

If you get a large number of rejections, try to reduce the number of requests from other programs or the amount of work *GHOST* has to do (drawing the current spectrum together with the acquired one, in logarithmic scale requires more work).

Please note that we didn't experience any problems of this kind, even using old 486 processors.

GHOST's spectrum viewer window can be iconified during acquisition, and screen saver can be run safely (for very long acquisitions, it would be better to shut off the monitor).

The shutter window signal is embedded in serial data by the acquisition circuitry and transmitted to *GHOST*. *GHOST* shows windowed channels in a different colour and allows the user to place them exactly on the edge of FSR peaks or undesired signals. No information about windows position is saved or loaded with spectrum files, and the window signal is visible only in observe mode or in the current spectrum during acquisition.

Please note that this function is available only using the latest acquisition box from JRS. This version of *GHOST* will work properly on older boxes, but if you want this feature to be available, please contact JRS for a hardware update of your acquisition box.

A further note on acquisition mode concerns acquisition when the IF control unit has the shutter in alt16 mode. Shutter detection is not operational in this mode and *GHOST* could appear "stuck" if you start acquisition while the interferometer is not getting data (i.e. during alignment cycles). You could get also a "no signal" error if the waiting time gets too long. In this case the solution is just to wait for the shutter to stop (data cycles) and then click the "start acquisition" button.

When the control unit is in the "x10" mode, irregular data flow from the interferometer can lead GHOST to think there are problems in the connection. An error message appears in these cases. A button has been introduced, allowing you to proceed anyway. Be careful since no consistency checks are made on the signal beyond this point (if GHOST remains stuck, close it using Windows' Task Manager).

3.2 Observe Mode

Observe mode is enabled by clicking on the corresponding button. Observe mode will show you the signal from the interferometer without accumulating any spectrum. This can be useful when aligning the interferometer or searching for best focus of the optics on a sample. The colour used for observation is the same as that used for the current spectrum during acquisition. Markers are not available in observe mode.

3.3 Information Window

If you click "show spectrum info" a window will be shown containing spectrum informations and comments gathered from a loaded file or set by yourself. It is the same window that *GHOST* uses when you select "show spectrum info after loading" in the general set-up dialog. For a description of the meaning of comments, refer to section 3.4 hereafter.

3.4 Comments Editor

The "edit comments" button activates the comments editor (Fig. 9), a dialogue used to set parameters of the spectrum. You can set sample name (not more than 40 characters) and other experimental variables. These values will be then saved on the spectrum file as comments.

GHOST can calculate the correct scan amplitude (in GHz) knowing mirror spacing, wavelength and scan amplitude in nanometers. To do this, simply edit one of the boxes - *GHOST* will do the job in "spreadsheet fashion"ⁱ. The accuracy of this estimate depends on the accuracy of the scan amplitude reading on the control unit. The JRS interferometer manual contains a procedure to check and calibrate the scan amplitude display of the control unit.

Please note that the "polarisation" field can contain only up to 2 characters, chosen from "HUVhuv". If you have any other requirement for polarisation you should use the extra comments text boxes.

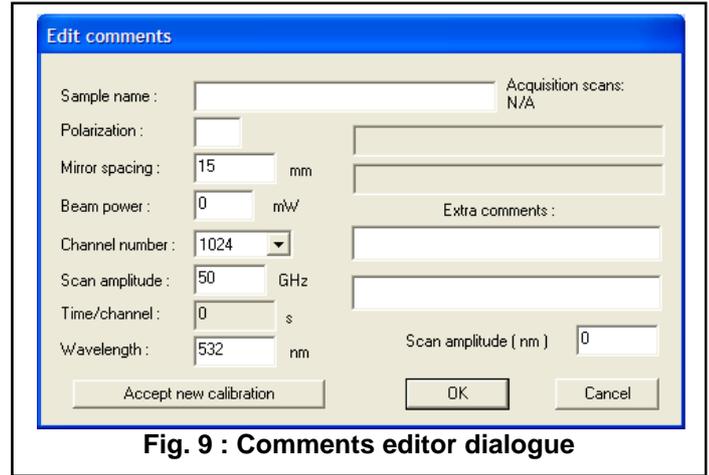


Fig. 9 : Comments editor dialogue

The lines on the right show the "free comments" (if enabled and configured in the "file structure" window) and extra comments. You cannot change free comments, but extra comments can be changed at will.

You can write up to 2 extra comments on any spectrum. They will be saved on empty lines before spectrum data. These lines can contain useful data about sample or experimental conditions, date etc. You can fix line numbers for free comments, while extra comments are placed on the first (two) lines available.

After an automatic calibration (sect. 3.7.3) the calibration of the spectrum (i.e. the scan amplitude in terms of frequency shift) will be locked. To change frequency scan amplitude manually, you must click "unlock calibration" button.

The number of scans already acquired in the current spectrum is reported at the top right of the window. The time/channel box reports the approximate time spent in acquisition on each of the spectrum channels; this is valid for all the channels but does not take into account the possible use of x10 mode acquisition : when this feature of the control unit is used, the time spent on the corresponding channels will be 10 times larger than that reported in this window.

3.5 Saving and loading in Raw Mode

Raw mode saving can be used if you want to generate a file containing only spectrum data, without any comment. The file will contain only a line for each channel, reporting frequency and number of counts (frequency is not reported in common spectrum files, but scan amplitude can be saved in comments). If you need to generate a plot using an external program, raw files will be useful. *GHOST* is also capable of loading a raw file. Scan amplitude and channel number will be detected by *GHOST*, but other parameters like sample name, mirror spacing and so on must be re-entered by the user if needed.

3.6 Default Spectrum

ⁱ The calculation of the scan amplitude is based on the assumption that a scan distance equal to half the laser wavelength corresponds, in the spectrum, to a frequency equal to the current FSR of the interferometer. Any different scan length will give a proportionally different scan frequency.

Every time *GHOST* starts up, it scans the program directory for a file named "default". If this is found, *GHOST* reads it and starts with the spectrum contained. This feature has been introduced to allow the user to set his own default parameters about scan amplitude, number of channels and so on. If you want to use this, just save a spectrum with this name in the program directory. If this file is not found, values are initialised to predefined amounts.

3.7 Data Analysis Toolbox

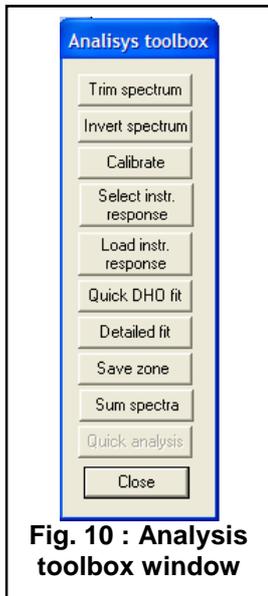


Fig. 10 : Analysis toolbox window

This window (Fig. 10) allows you to fit curves to a spectrum and verify your results. The fit program has been developed starting from a standard Levenberg-Marquardt routine. The window is activated if you click on the button in the main window. A window will appear on the left. Just press any of the buttons to access the functions. Several of the functions in this window require the markers in the main window to be correctly placed, to identify a region in the spectrum.

The first available function is the "trim spectrum" feature. This clears spectrum data between the two markers; it can be used to remove interferometer ghosts or a central peak, if desired. A confirmation dialog will be shown.

The second button will invert the spectrum: the absolute maximum of counts will be calculated and every channel will be set to the difference between the maximum and the previous value. This function is commonly useful only when calibrating manually (see the appropriate section for details).

The "Select instrumental response" button allows the user to select a part of the spectrum to be used as an instrumental response. The corresponding points are saved in memory and used during data fitting routines (see detailed fit function section). After this button is pressed for the first time, it remains in the "pressed" state; afterwards you can change the response function in four ways:

- by placing again markers (or moving them from their previous position) and clicking the button again - this replaces the currently selected instrumental function with the new one.
- by deactivating markers and clicking the button again - this erases any response functions selected.
- by closing the analysis toolbox - the response function is erased, too.
- by loading a response function from a file (see next page).

The "save zone" button saves the zone of spectrum between the markers in a format similar to the RAW data file: just a frequency and the related number of counts. Optionally the number of channels saved can be saved on the first line.

The "Load instrumental response" allows you to load an external file containing a response function. *GHOST* expects it to be a text file, in which the first line contains the total number of points following and each line contains a frequency and an integer proportional to the value of the response function. The channels in the response function must be equally spaced, even if the spacing can be different from the current spectrum's one. This format is identical to the one produced by pressing "save zone" you can thus save the response function of a spectrum and use it for many others if needed.

The response function is always normalized internally before use; the zero frequency channel can be identified in two ways: either the channel with the maximum count number ("centering mode") or the channel having the smallest absolute value of frequency ("non centering mode").

Response functions taken from the current spectrum with the "select instrumental response" function are centered automatically, while for external files you must select if you want centering or not.

For information about the use of "Calibrate", "Quick DHO fit" and "detailed fit" functions please refer to the appropriate sections of the manual hereafter.

The "sum spectra" button can be used to sum two spectra with the same scan amplitude, even having different channels number. The spectra are summed channel by channel and can be saved as standard or raw spectrum data files. The result of the sum can be optionally selected as new current spectrum; it is also possible to force a summation of spectra with different scan amplitude : in this case the resulting scan amplitude will be set to the average of the two starting ones. .

3.7.1 Quick DHO Fit

To use the quick DHO fit feature, first select a data interval in the main window by placing it between markers and then click the button - *GHOST* will try to do a data fit using a DHO model function on the selected data region. The model function used is the following:

$$I_{DHO} = B + \frac{I}{4\pi} \frac{4\Gamma f_0^2}{(f^2 - f_0^2)^2 + 4f^2\Gamma^2}, \quad \text{Eqn. 1}$$

where B is a baseline, I an intensity arbitrary factor, Γ is the peak half width in frequency units (GHz), and f_0 is the peak frequency.

This procedure has been selected to give you results as soon as possible, so in a very short time a window should appear, indicating the final results of the fit (with uncertainties) and the corresponding value of reduced χ^2 obtained by the fit routine. Please note that this function uses a pure DHO to fit the points and does not apply any convolution or subdivision to the theoretical model, even if in the toolbox an instrumental response function has already been selected. The 4 adjustable parameters of the model are all guessed automatically and left free to change during the fit.

At the bottom of the "Quick DHO fit" window there are buttons to get a visual representation of the theoretical curve and to save parameters values to a file. If you press the "show fit on main window" button, the model curve corresponding to the final values of the parameters is shown on the main window (Fig. 11); the colour used can be chosen from the "visualisation setup" window.

A very useful control is the "Add to GRAPH.TXT" button: it becomes enabled when you use the fit routine (at least once) and allows you to save all fit data on a file (GRAPH.TXT, in the *GHOST* main directory). If you are satisfied with your fit, just click this button to save it as a row in the text file.

Each row of GRAPH.TXT contains a parameter and all the final fit parameters with their uncertainties. When you press the button, *GHOST* will search the current filename for a number; if found, *GHOST* will pop-up a window suggesting this number as a parameter identifying the current fitting session, but allowing you to change it if you want.

For example: if the spectrum file PMA234.SPC is loaded in the main.window and you make a fit on a peak, *GHOST* will suggest 234 as a parameter. This is useful if you use a temperature or a pressure in the file name. If a number is not present, the suggested parameter will be zero and you can choose one by yourself.

In the "Quick DHO fit" window the fitting procedure can be repeated. If you move the markers (to select another peak or to select a slightly different region of the same) and press the "fit again" button, a new fit procedure will be performed immediately.

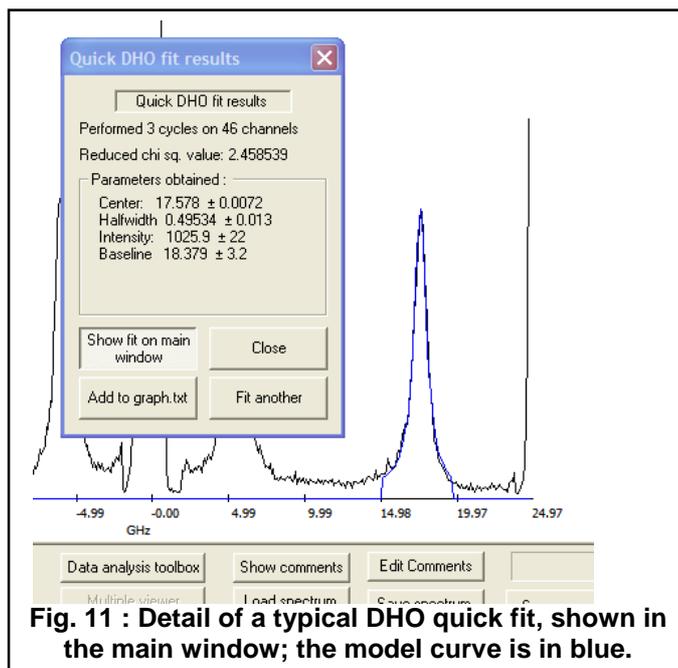


Fig. 11 : Detail of a typical DHO quick fit, shown in the main window; the model curve is in blue.

3.7.2 Detailed Fit

The detailed fit window () allows you to perform data fitting using different models on a selected part of the spectrum. The dropdown box at the top left of the window will allow you to choose among DHO (Eqn. 1 in paragraph 3.7.1), lorentzian or gaussian model (described below in sections 3.7.2.1 and 3.7.2.2). The spectrum zone must be selected before clicking the button. The window will then appear with values automatically guessed to be near the correct ones. The parameters of the fit are reported at any time in four edit boxes, with their statistical uncertainties if available. Values can be changed, editing directly, or by pressing the spin buttons on the right of each box (each step corresponds to 0.001 of the starting value). The curve in the zoom on fit window, if this latter is open, is redrawn after any change. You can set free, or keep fixed, one or more of the parameters by checking the box on the left.

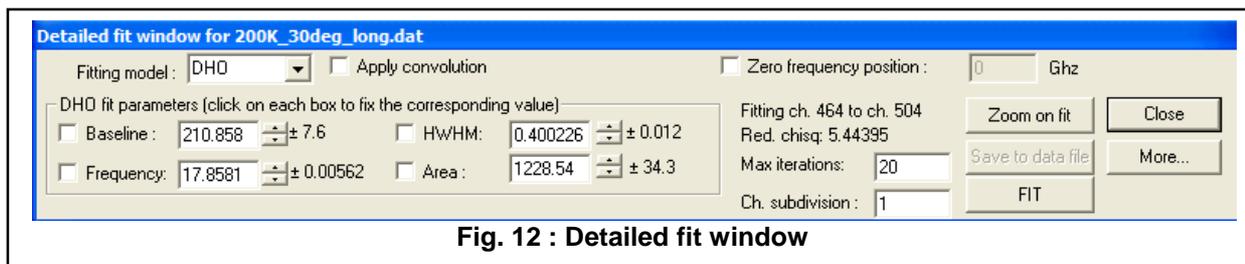


Fig. 12 : Detailed fit window

The "zero frequency position" function is useful to take into account the asymmetry of the spectrum, i.e. reassign the elastic position to a non-zero value of frequency. Usually you can quantify this value performing two quick DHO fit on two corresponding well resolved features and taking half the absolute

value of their frequency position difference. If the box is checked, GHOST shifts the spectrum points before any fit operation and obtains corrected values at the end of the fit. This allows also a check of the goodness on both features using the zoom on fit window (see par. 3.7.2.2), which shows the corrected curve.

You can select the maximum number of iterations to do during fit and channel subdivision (see par. 3.7.2.1 below) on the boxes on the right.

After a fit is started using the appropriate button, a progress bar will be shown. The process can be aborted at any time by pressing the "abort" button on the progress window: in this case values will be restored to initial ones.

After the fitting process is complete, the new values of the parameters and uncertainties are shown and the new curve is redraw in the "zoom on fit window" (if open).

The "save to data file" button is enabled when the selected region has been analysed at least once. It works in the same way as its mate in the "quick DHO fit" window, i.e. saving parameters in the file GRAPH.TXT, with the same meaning of the columns.

The "zoom on fit" button opens a graphical window useful to check the goodness of fit (see par. 3.7.2.2 below).

You can modify your selection of the points to be analysed by using the same keys (A-D, J-L) used in the main window, without exiting the detailed fit mode. Please note also that you can load other spectra from the main window without exiting the data analysis toolbox, and you can edit comments as well. The fit routine takes frequency data from the spectrum scan amplitude, so ensure the scan amplitude is correct before making data analysis on a spectrum (see section 3.7.3 below).

When the detailed fit window is open, a new peak to be analysed can be selected by positioning markers and clicking the "detailed fit" button again. The zoom-on-fit window will reflect changes and values of parameters will be initialised to good starting points. The fit routine must then be started by the user.

The "More..." button opens a little window which allows you to save to a three columns data file containing results of the fit you performed. The first column will contain frequency, the second one the experimental value and the third the DHO fit value obtained. The corresponding parameters values can be optionally appended at the end of the file. Other functions will be made available there in the future.

3.7.2.1 Lorentzian lineshape fitting

When the lorentzian model function is selected, the following expression is used for fitting:

$$I_{LOR} = B + \frac{I}{\pi} \frac{\Gamma}{(f^2 - f_0^2) + \Gamma^2} \quad , \text{Eqn. 2.}$$

Here again B is a baseline, I an intensity arbitrary factor, Γ is the peak half width in frequency units (GHz), and f_0 is the peak frequency.

3.7.2.2 Gaussian lineshape fitting

Using the gaussian model function, data will be fitted using the expression :

$$I_{GAUSS} = B + \frac{I}{\sqrt{2\pi}\Gamma} e^{-\left[\frac{(f-f_0)^2}{2\Gamma^2}\right]} \quad , \text{Eqn. 3.}$$

The meaning of the parameters is the same as for the other two models: B is an arbitrary baseline, I an intensity factor, f_0 is the peak position and Γ is the half width, in frequency units (GHz).

3.7.2.3 Convolution and Channel Subdivision

The fit routine can convolute the theoretical spectrum with the instrumental response function while doing fits using the DHO model function. The convolution is enabled if you check the "apply convolution" checkbox before fitting. Obviously you must select this curve before doing this, as described in par. 3.7.

The convoluted curve is shown against the experimental points if the "zoom on fit" window is open. You can safely change the convolution function or deactivate it without closing the detailed fit or the zoom on fit windows.

The fit routine supports also increasing the resolution of the theoretical curve with respect to the experimental points by channel subdivision. When the peak to be analysed is narrow, you can use this feature to increase the sensitivity of the fit routine. The subdivision ratio is the number of points in the theoretical curve for each spectrum channel. Obviously subdivision and convolution make the fit routine slower, and cannot raise the resolving power of the instrument.

3.7.2.4 Zoom-on-Fit Feature

The "zoom-on-fit" window (Fig. 13) shows an enlarged graphical image of the points currently selected for fit in the detailed window. The model curve and the baseline corresponding to the current values of parameters are also shown. You can move toward the left or the right using the scrollers, and the image can be further enlarged up to a factor 5x (seldom necessary).

The colours used for this visualisation are selected using the visualisation setup window. You can distinguish points being analysed from others because they are shown in different colours.

The keys can be used to move the markers and change the selection to fit even when the zoom-on-fit window is open. A change in the parameters causes the image to be redrawn immediately to reflect changes.

If channel subdivision is enabled in the detailed fit window, the drawing routine can be slower; the time request for a repainting depends on the number of subdivisions, number of points to be analysed and speed of your machine.

3.7.3 Automatic and Manual Calibration

When you analyse data using *GHOST*, peak positions and widths are estimated using the spectrum scan amplitude, giving a resolution in terms of GHz per channel. If you perform high precision measurements, you need a good estimation of resolution and/or scan amplitude as a starting point. Calibration allows you to obtain these data from a "calibration spectrum".

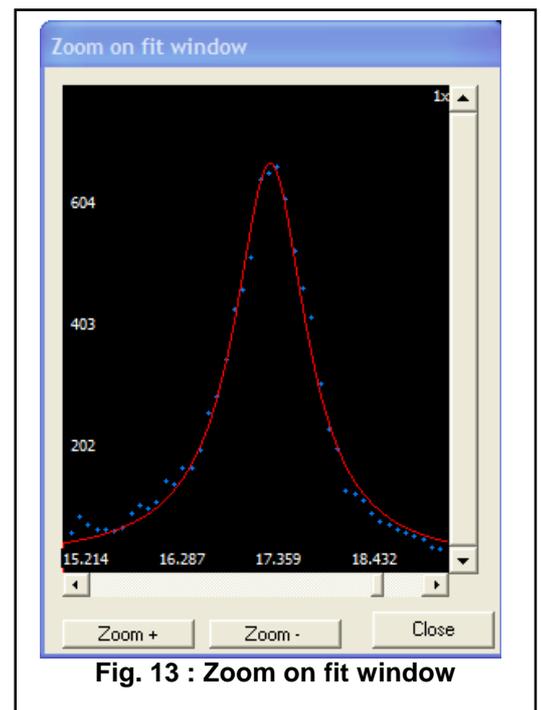


Fig. 13 : Zoom on fit window

To take a calibration spectrum, just make some acquisition scans (usually 20 or 30 cycles are sufficient) while your interferometer is in the alignment mode and when mirror spacing and scan amplitude in the control unit are already set to the correct values for your experiment. Note that the stabilisation loops for the interferometer cannot function in the alignment mode, so it is essential to make sure the stabilisation is switched off for this measurement. To obtain a good calibration the first pair of mirrors (FP1) should be reasonably well aligned, while the second pair (FP2) should be far from a perfect condition, producing broad, irregularly shaped peaks not superimposed on the FP1 ones.

You will see a spectrum with several absorption peaks belonging to the two interferometers. Using the "edit comments" window select the correct mirror spacing, then place the two markers on two adjacent peaks belonging to the first interferometer and press the "calibration" button in the data analysis toolbox.

The automatic calibration will estimate peak positions, calculate a distance (as number of channels) and a resolution assuming that the distance between the peaks (in frequency) is equal to a "free spectral range". If the markers are positioned near to both the peaks, the calculation is quite good. The calibration routine will show you a dialog with results; if you accept calibration data the scan amplitude for the current spectrum will be set to the calculated one. You can obviously note the value for future reference. You need to save the spectrum in order that the new calibration data is updated in the file.

To prevent undesired loss of a calibrated scan amplitude, *GHOST* keeps "calibration locked": after an automatic calibration, the frequency scan amplitude will remain the same until a new (automatic) calibration is performed or until you unlock and change it manually from the "edit comments" window. Calibration status is reported on the status text line in the spectrum. When you load a spectrum, *GHOST* can load new data keeping the current calibration (it will ask you).

If you need even more precision, you can calibrate manually: once you have a calibration spectrum saved, use the "invert spectrum" button to invert it and select a fictitious scan amplitude, for example 1024 GHz on a spectrum of 1024 channels. Doing so, you will have a numerical correspondence between channel number and frequency. Now select the two calibration peaks individually and fit them. You can verify the correctness of the fit as described in paragraph 2.7.1 or 2.7.2. The "peak frequency" will be a channel number.

Take the difference (as channel number) between the two peaks' frequencies and calculate FSR manually. You will have a very accurate value for scan amplitude and resolution.

A manual calibration can be performed by any suitable software, by saving in raw mode the inverted spectrum. If you use *GHOST* functions, please note that the DHO model function used in the "quick fit" or "detailed fit" procedures may not be reliable in estimating the peak position when a peak is very near to zero frequency, as could happen in a calibration spectrum. In order to obtain reliable estimate of the calibration peak positions even when a peak is at near-zero frequency, do a detailed fit selecting a gaussian or a lorentzian model function.

3.7.4 Saving a Spectrum Region

The "save zone" button in the analysis toolbox allows you to save a region of the spectrum, selected using markers. The output file will be composed of two columns of numbers, corresponding to frequency and number of counts for each of the selected channels. Starting from this version, *GHOST* asks you if you want the number of points to be saved on the first line of the file. In this case obviously the first row is composed of a single column.

3.8 Multiple Spectrum Browser

The multiple viewer button activates an additional window, developed to allow an easy and quick comparison between spectra acquired with the same frequency scan amplitude, but eventually with a different choice of experimental parameters or number of channels. The multiple spectrum browser window is shown in Fig. 14.

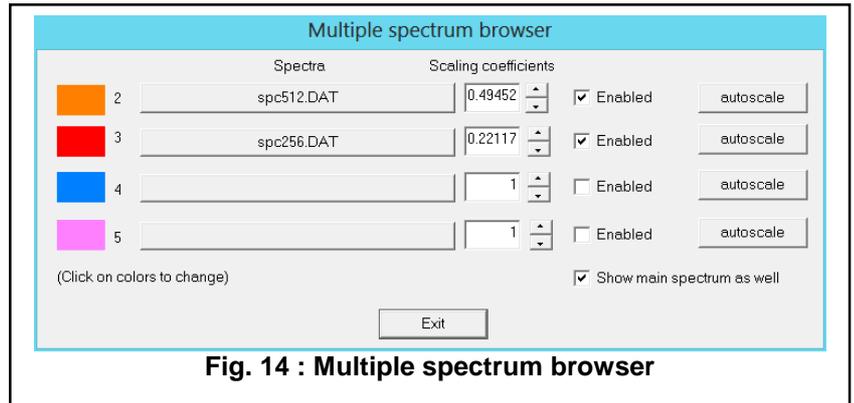


Fig. 14 : Multiple spectrum browser

On the left, you will see the colours you selected in the visualisation set-up window; by clicking on the coloured box, you can change them also from there, but the changes will not be stored for future sessions.

Using the four buttons, you will be able to load up to 4 additional spectra, to be shown on the main window. The name of each additional spectrum file will be shown as a caption on the button. You can enable and disable each of them separately, and fix independent additional scaling coefficients. Each of the "autoscale" buttons selects a guessed scaling coefficient for the corresponding spectrum. You can change the spectra by clicking again on the buttons; you can globally zoom in or out using the controls on the main window, and the log/lin, line/dots radio controls are active as well.

Please note that the main spectrum will not be erased if you enter the multiple viewer and it can be visualized together with the additional ones, using the checkbox in the lower right part of the window.. The multiple viewer will not rescale horizontally spectra with different scan amplitude, will not change the main window x and y scaling or the number of channels displayed; it is possible to select additional spectra having a number of channel different from the main one.

3.9 Automatic mode acquisition

By pressing the ALT+A key combination when the spectrum window is idle, a small window will open, which is shown in Fig. 15.

This window allows to perform a series of measurements, each one corresponding to a fixed number of acquisition cycles and sequentially numbered. The parameters of this operation can be selected using the text boxes in the window.

The files will be saved in GHOST's program directory; a status caption on the bottom of the window will show the current status during operation.

The automated mode acquisition procedure can be stopped before completion by pressing the "close" button.

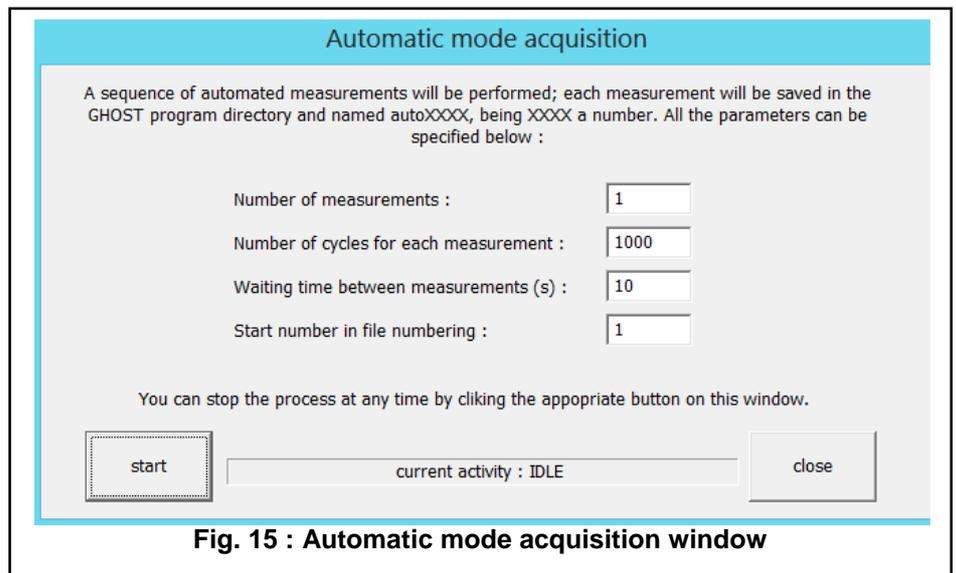


Fig. 15 : Automatic mode acquisition window

3.9.1 How to print out a Spectrum

GHOST can't save directly a spectrum image or print. If you need an image of the spectrum window, however, you can hit "PrintScreen" key. On most Microsoft Windows systems, this will save an image of the whole screen in the system clipboard, allowing you to paste it later to any document. Of course, you will need a basic image editing program to cut off all the parts of the screen you don't need.

4 NETWORK OPERATION

4.1 General Description

Our aim in providing network support in *GHOST* is to achieve an effective interaction between our program and other laboratory devices. Of course, nowadays it is easy to find in a laboratory a lot of simple devices connected and controlled by PCs and the availability of network connections is quite ubiquitous. If you have a temperature controller or another control device connected to a PC and involved in your experimental analysis, you could be interested in starting/stopping the acquisition remotely or automatically. Moreover, if your laboratory (dark and noisy) is not your best place to work, you might also like to observe your acquisition from another workstation, while your interferometer is taking data. In order to interface with the acquisition system at a lower level, for example from a user-made software or from a LabView script, a primitive network access is useful.

For these reasons you can now enable network operation in the "general set-up" dialogue (Fig. 5); *GHOST* can operate in "server" or "client" mode: the server is usually the copy of *GHOST* that is taking data, while all the other copies of *GHOST* running in the network should be clients. You can even have multiple copy of *GHOST* running on the same PC, but only one of them should be the server.

GHOST server copy will try to open a TCP/IP network port (port number 4000) and will listen for messages here. *GHOST* clients are able to establish a connection to this port and use a specialized network protocol to communicate with the server. The protocol used is telnet-like : this means you can interact with a *GHOST* server using telnet program and your keyboard: you will find information on the text commands currently available thereafter.

GHOST clients can pass command to the server by simply translating the activation of a button into a network command issued to the remote server.

In the general setup window (Fig. 5), we introduced a box in the bottom to allow access to the server only to specified network addresses. A value of 0 or 255 in any field of the IP address is a wildcard (i.e. will allow access from IP addresses containing any number in that position), while any different number will filter connections. Two examples: 255.255.255.255 will allow connections from any location, while 141.250.2.255 will allow connections only from addresses belonging to the network 141.250.2.

In the unlikely hypothesis that you want to run two copies of *GHOST* on the same physical PC, connecting them one to the other, you can start the server copy and then start a second one as client without changing the setup settings, using the `--client` command line option in a command prompt window (typing : `GHOST --client`).

Before proceeding with the description of the protocol, we should add a word of advice: the network functions have been tested but, as the reader can easily imagine, it's very difficult to reproduce all possible applications, and only a small subset of *GHOST* users is really interested in them. If you experience any trouble with network support, please contact us.

4.2 Server-side Network Dialogs and Functions

Two dialogs open only when you operate *GHOST* in server mode: one each time when you start the spectrum viewer and a second one when you click the "Network..." button in the spectrum window itself.

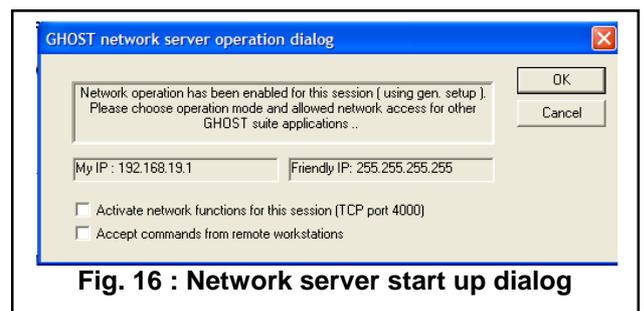


Fig. 16 : Network server start up dialog

The first dialog (Fig. 16) allows the user to enable or disable the network functionalities for that session (i.e. as long as the following spectrum viewer window is active), without changing the main settings in the general setup window; you can also enable or disable the remote control capability, specifying if you want the server to accept commands from one of the connected clients or not.

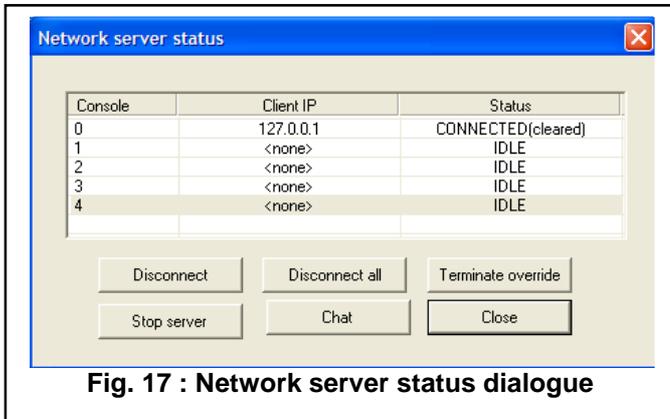


Fig. 17 : Network server status dialogue

The second dialog window (Fig. 17) allows you to see if any client is connected to the server and which is the address of any of the clients. Up to 5 clients can be connected at a time, but only one of them can be allowed to issue commands to the server. The same window contains buttons that allow you to close one or all of the connections, terminate the network server activity, activate a "chat" window with one of the clients, or terminate the "override" state.

The "override" state is the state of a client that has taken remote control of a server. Clicking the

"terminate override" from a server when a controlling client is selected will take back the control to the local buttons. When a remote client takes control of the local (server) *GHOST* some of the buttons in the spectrum window will be not available. This is to prevent dangerous superposition of commands between the local and remote console.

The "chat" window is a minimal service which allows short text messages to be sent from client to server and vice-versa. Just write your message in the edit box and click "send"; any reply will be visualized in the line just below.

Please remember that, when you close the spectrum viewer window the network socket is reset and all *GHOST*'s connections (incoming in the server or outgoing in the client) are closed.

4.3 Client-Side Network Dialog and Functions

The network client dialog (Fig. 18) opens when you click the "Network" button in a *GHOST* client. This little window accepts as input the IP number of the server *GHOST* to be called and a refresh interval in units of 100 ms. This will be the interval of the data polling: the client will ask the server to update the spectrum data; slower update rates will make lighter the interaction between the client and the server, and will not stress a slow network connection. The little checkbox on the right will make the client attempt to get remote control of the specified server.

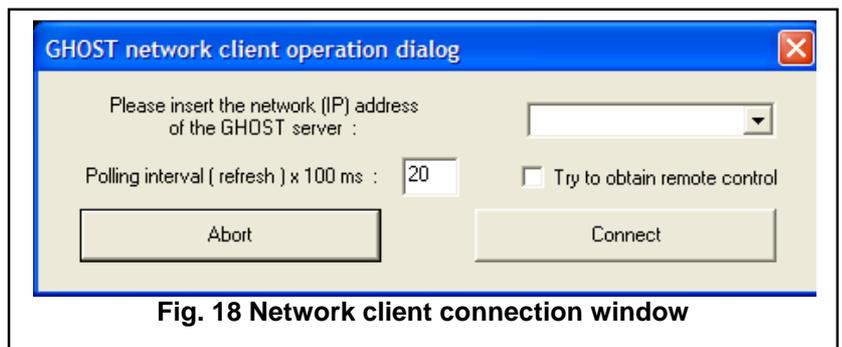


Fig. 18 Network client connection window

After the network client window is closed, *GHOST* will show the results of the network connection attempt, and the main spectrum window should display the data of the current spectrum of the server, refreshing it at the chosen rate. If the client managed to obtain remote control of the server, the buttons will work controlling remote actions instead of locals.

When a client is connected, the "Network..." button in the main spectrum window allows disconnection; closing the spectrum window also leads to disconnection. The "chat" capability is available by pressing the ALT+C combination.

4.4 Network Protocol

This section gives a brief description of the network protocol developed for *GHOST* network connections. The protocol implements a minimal interface to allow remote control from any program capable of making a TCP/IP connection and send text over it.

The connection must be made to port 4000; *GHOST* will first reply with a welcome string and a prompt. The available commands and their formatting information are:

<i>CLOSE</i> :	closes the connection.
<i>CHAT</i> ".." :	sends the text between double quotation marks to remote <i>GHOST</i> , up to 80 characters in length.
<i>DATA</i> :	this command is for internal use only.
<i>DELETE</i> :	delete server's current spectrum data.
<i>HELP</i> :	shows help on commands.
<i>STATUS</i> :	shows <i>GHOST</i> status information.
<i>OBSERVE</i> :	starts signal observation.
<i>OVERRIDE</i> :	tries to get control of the server.
<i>SAVE</i> <name> :	saves current spectrum on file <name> in the current work directory on the server (chosen with <i>WDIR</i>). No spaces allowed in <name>.
<i>SAVERAW</i> <name> :	Same as the <i>SAVE</i> command, with raw output file format.
<i>SET SHOW_CURRENT</i> :	activates the display of real-time spectrum during acquisition on server.
<i>SET256,SET512,SET1024</i> :	sets the number of channels.
<i>START</i> nn :	starts acquisition with nn cycles on the server.
<i>STOP</i> :	stops acquisition or observing mode.
<i>TEXT</i> :	this command is for internal use only.
<i>RESTORE</i> :	restore local control mode on the server.
<i>WDIR</i> <name> :	sets the subdirectory <name> as current working directory on the server. This directory will be created (if not present already) as a subdirectory of <i>GHOST</i> main working dir.

Please note that the *DELETE*, *OBSERVE*, *SET SHOW-CURRENT*, *SAVE*, *START*, *STOP*, *WDIR* will work only when the client has taken control of the server (using the *OVERRIDE* command).

5 FUTURE UPDATES

5.1 Our goals in next Releases

In one of the next releases we would be happy to add:

- real-time check of stabilisation

5.2 How to report bugs

We'll be listening for bug reports at f.scarponi@jrs-si.ch. Should you find a software bug, please report it in as much detail as possible, so that we can work on it. We'll appreciate suggestions and comments about *GHOST* too. If you have a good idea for making it more useful or a feedback about the behaviour of the application on unusual platforms, please send us a mail too.

5.3 Troubleshooting

Problems with file configuration: if you have trouble loading and saving spectra, your configuration file has probably got corrupted. You can use the "reset configuration" button in the general setup window in this case. Then, you have to re-edit and save your configuration. The extension TXT for spectrum files allows you to open them with Windows notepad.

Acquisition hangups and automatic calibration failures: *GHOST* could exhibit hangups during acquisition and observation and/or more or less frequent wrong results of automatic calibration. This shows up occasionally on slow machines (486s or Pentiums) and old operating systems. In these cases try to disable "heavy" functions as displaying of real-time spectrum, log scale and network; to obtain calibration use the manual procedure described in section 3.7.3.

Video problems: usually you need only to restart *GHOST* if you experience video problems (windows missing some part, buttons not present ...)

Problems with automatic calibration: if *GHOST* shows a "zero distance between peaks" error message, try to move one or both the markers around the absorption peaks and repeat the operation. Sometimes the program makes mistakes while attempting to automatically select the peaks areas, thus moving slightly the markers can be useful. If the error persists, it could be due to a bad S/N ratio in the calibration spectrum; you could try recording more acquisition cycles.

Problems with network connection: problems in connections may arise, using windows XP systems, from the activity of the system firewall: port 4000 should be enabled for incoming connections if the server runs on a XP system with firewall active, or the firewall is to be deactivated completely. The same kind of problem can come out if you try to connect to a *GHOST* server running behind a firewall. In this case the firewall must be set to allow incoming connections towards port 4000 of the server PC.

Note that also several antivirus programmes have internal firewalls acting independently from the system; these also can act to block incoming unknown connections and prevent the server from working correctly.

If both the server and the client are behind the same firewall, these problems should not exist, so check the configuration on the server, particularly the netmask in the general setup window.

Notice:

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