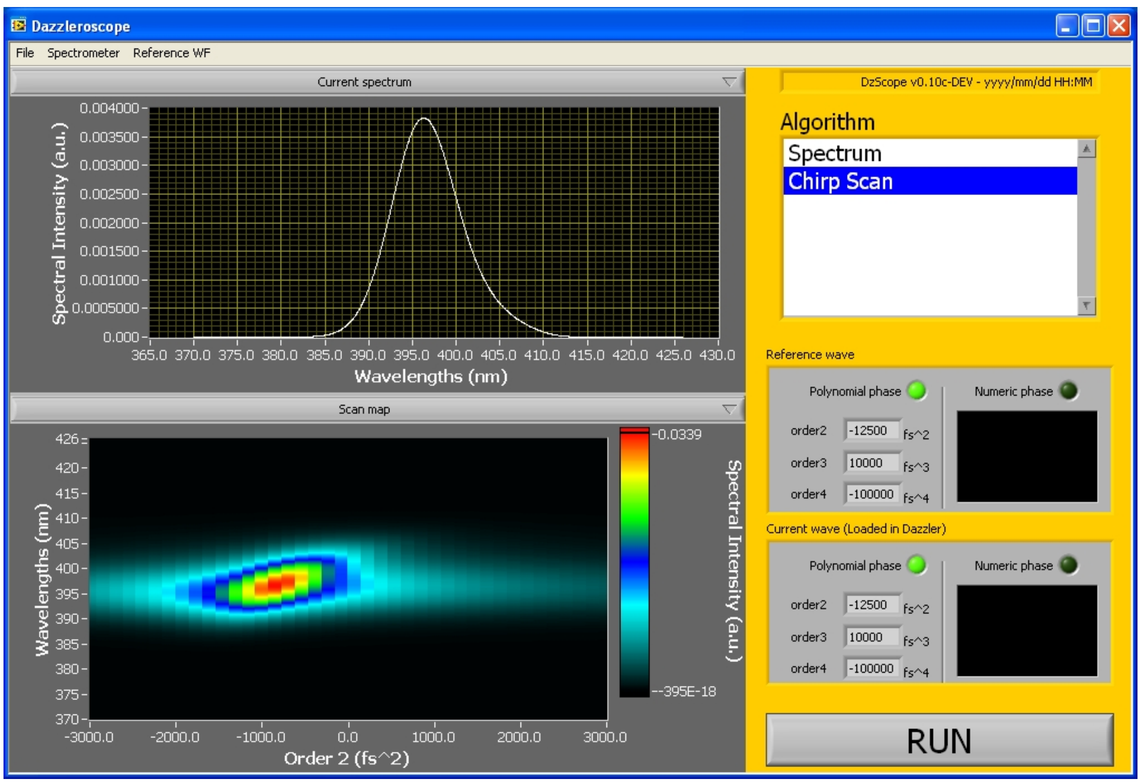
DAZSCOPE SYSTEM OPERATING MANUAL

9 september 2008



FASTLITE - info@faslite.com

CONTENTS

CHAPTER

1

INTRODUCTION

1.1 What the DazScope is

The DazScope is a pulse controller system primarily designed to optimize the pulse duration of ultra-short (<100fs) laser systems. It comprises a pulse shaper, a simplified pulse characterizing device and a feedback algorithm providing closed-loop measurement and manipulation of ultrafast pulses. Unlike pulse measurement techniques such as Frequency-Resolved Optical Gating (FROG) techniques or Spectral Phase Interference for Direct Phase Reconstruction (SPIDER) techniques, the method used to characterize the pulse is a *phase-only* method. Consequently, the pulse shaper may be safely inserted at any stage within the laser chain (see figure 1.1 for a typical architecture).

The DazScope is based on the pulse-shaping device commercialized by FASTLITE under the trademark Dazzler, and can be provided both as a an add-on for existing Dazzlers or as a stand-alone system. The main part of this system is a complex software that remotely controls the Dazzler pulse shaper in order to optimize the spectral phase.

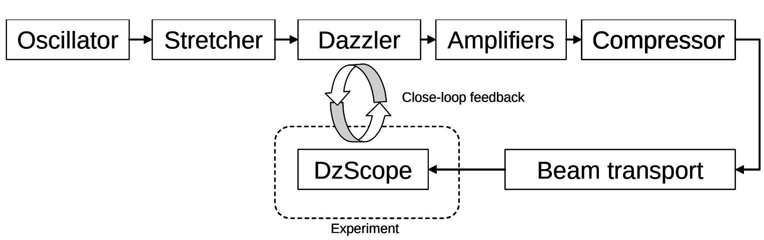


Figure 1.1: CPA configuration

1.2 What the DazScope is not

Although the DazScope was designed and developed to be as user-friendly as possible, it *cannot* fully replace an intelligent operator. More precisely, the DazScope cannot be expected to correct spectral phases which exceed the pulse shaping capabilities of the Dazzler used in conjunction with the DazScope. This is why the optimization procedure is semi-automatic and requires, in the basic mode, a few operations from the user.

The DazScope is based on a characterization technique described in chapter 5. It must be underlined that as any phase-only method, this algorithm is *not* a pulse measurement technique comparable with the FROG or SPIDER techniques: the DazScope is only relevant for pulses with sufficiently regular spectra and sufficiently smooth spectral phases. The pulses delivered by chirped pulse amplification (CPA) laser systems typically verify such specifications. However, a double pulse structure, for example, will not be correctly measured nor corrected.

CHAPTER

2

INSTALLATION

To install from scratch, please follow the instructions given in section 2.1, section 2.2 and section 2.3. To install the DazScope on a laser system already including a Dazzler, the reader may go directly to section 2.3.

2.1 Software

The DazScope software is a LabView 8.5 executable file. To run correctly, it requires both a Labview 8.5 runtime engine and a correctly installed Dazzler software (version v4xx required). To install or update the DazScope software, please follow the steps indicated below [1]:

1. Install or re-install the Keyspan driver, the Labview run-time support drivers and the Dazzler software (see appendix chapter A).

2. Install the spectrometer driver (`CDROM:\spectro-drivers\AvaSoft_7.x.x USB2.zip` - this file must be first unzipped.)

3. In case the DazScope was previously installed, use the uninstall option of the DazScope program group (Start>All Programs>DzScope>unistall_DzScope).

4. Install the DazScope Software (`CDROM:\#Installer_DzScope\setup-DzScope-xxx-exe.exe`)

5. Check that a "`DS`" directory is present in the parameters directory related to the Dazzler system (to learn more about the Dazzler parameters directory see the dedicated notice chapter B).

[1] This section complements the readme file located on the CDROM in the installer directory.

6. In case this folder is missing, copy and paste in this directory the appropriate "`DS`" directory. The "`DS`" directory contains all the custom parameters required by the DazScope software. To date, there are two sets of standards DazScope parameters, `DS-HR800` and `DS-WB800` which are located at `CDROM:\parameters_hoard\StandardParameters\DzScope`. Do not forget to rename the suitable directory into `DS`.

7. Start the Dazzler software, and update the paths (In the Dazzler software: Monitor > maintenance > set paths).

8. Edit the file `C:\dazzler\paths.txt` and add a new line containing the text `params =` followed by the path of the Dazzler parameters directory.
   Exemple: `params = E:\DZSOFT\parameters_hoard\DB00-99\WB\db08wm29-v415`. Save the file `C:\dazzler\paths.txt`.

The software is protected by a USB dongle. If the DazScope program is started without the dongle, you get the message: "SG-Lock not found, Program will stop. This is a FATAL error! Program will exit."

2.2 Dazzler setup

2.2.1 Beam Orientations

The angles indicated refer to the WB models. Note that the polarization and the direction of the diffracted beam are different from the input beam. Make sure that the output polarization fits your laser setup.

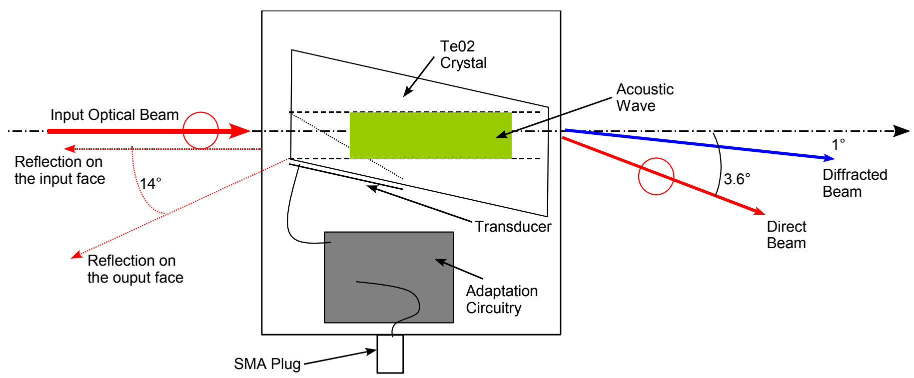


Figure 2.1: Top View (laser pulse propagation from left to right). Input polarization is orthogonal to figure plane. Diffracted beam is polarized in the diffraction plane (figure plane).

2.2.2 RF Generator Triggering

To trigger properly the Dazzler, you need to feed a TTL signal from the laser, with a rising edge occurring *before* the laser pulse to be amplified enters the Dazzler crystal. This time interval must correspond at least to the acoustic propagation time inside the crystal[2] . The triggering configuration varies with the experimental setup (10Hz, kHz lasers). Operational details are described

[2] The acoustic propagation time depends on the crystal cut. For 25mm crystals, this is 31.6μs for the WB cut, and 40.6μs for the HR cut.

in the note "trig_mode_settings", while more technical details can be found in the note "Trigger" (both files can be found on the CD-ROM).

2.2.3 Getting Ready to Operate the DazScope

Connecting the Unit and Starting the Program

1. Connect the USB cable to the host computer
2. Connect the RF output to the crystal unit.
3. Turn on the power switch on the rear panel of the RF generator. The waveform memory is zeroed at power on: no RF output.
4. Double click on the Dazzler icon on the desktop. The program is automatically started.
5. Connect the trigger signal (less than the acoustic travel time before laser pulse - see subsection 2.2.2) to the Trigger Laser input on the front panel.
6. Check that the second diode on front panel lits.
7. Use the menu "Setup > trig and mode" to set the proper trigger delay (starts the panel).

Alignment and Calibration of the Dazzler

Please refer to appendix C.

Power and Duration Parameters (blue area)

1. Set the `power level` to 0.5.
2. Uncheck the `CG` box (no constant gain).
3. Select the `new` option in the `action` listbox.
4. Select `Load In...A` with the button switch.
5. Set the `add waveform` button to off

Amplitude parameters (red area)

1. Select the `dials` item in the listbox located just below the red `Amplitude` label.
2. Set the central wavelength (`position`) to a value appropriate to the laser source : ideally, this value should be equal to the central wavelength of the input pulses. When the Dazzler is placed before the laser amplifier(s), this value may significantly differ from the central wavelength of the amplified pulses, especially when strong spectral gain narrowing or red-shift effects are present in the amplification stage[3].

[3]It is not unusual to set "position = 800" and to measure amplified pulses at 810-815nm.

3. Set the `width` control to 2 or 3 times[4] the FWHM spectral width of the input or amplified pulses plus the value of the potential redshift[5].

4. Set the `hole depth` control to 0.

Phase parameters (green area)

1. Select the `dials` item in the listbox located just below the green `Phase` label.

2. If the central wavelength of the amplified pulse (λ_0) is close to the value of the `position` control, check the `Auto` checkbox located at the bottom of the phase control (green panel) area. If this is not the case, uncheck this checkbox and enter manually the value of λ_0 in the `Central wavelength` control. This will ensure that the spectral phase coefficients will refer to the right central wavelength[6].

3. Set the delay dial to a value corresponding to half of the maximum crystal delay (for example, 1700fs for 25mm WB-800), verify that the mean position on the time display is in the middle of the window.

4. Press the `SelfC` button which is located on the left of the `Phase` listbox. This will automatically set the phase coefficients to compensate for the dispersion of the Dazzler crystal.

5. Check that the spectrum graph does not show separate red and black curves. If so, check maximum delay and reduce second order parameter (order 2) if necessary.

Trigger parameters

Since all laser systems have different synchronization managements, it is difficult to specify a universal process to set up the trigger parameters. Here is however, the most common way to proceed:

1. Click in the `Setup` menu, select `Trig and mode` : this will open the corresponding panel.

2. In the `Trigger mode` listbox select `External Source`.

3. Check that the displayed repetition rate is correctly measured by the generator. If the displayed repetition rate is wrong, check the trigger signal (see subsection 2.2.2).

4. In the `Delay Mode` listbox select `Programmable Trigger Delay`. This will activate the delay generator module of the RF generator.

5. Check that the `Trigger on previous` checkbox is *not* checked.

6. In the `Trigger to Laser` control, enter the delay between the trigger signal (TTL rising edge) and the laser pulse[7].

[4] This is a rule of the thumb.

[5] E.g.: for an amplified spectral width of 30nm with a red-shift of 10nm, the width control must be set to 100nm

[6] The phase coefficients (second order, third order etc) refer to a Taylor expansion of the spectral phase around λ_0. If "auto = 1", λ_0 is assumed to be equal to the "position" amplitude control

[7] with a microsecond accuracy at least

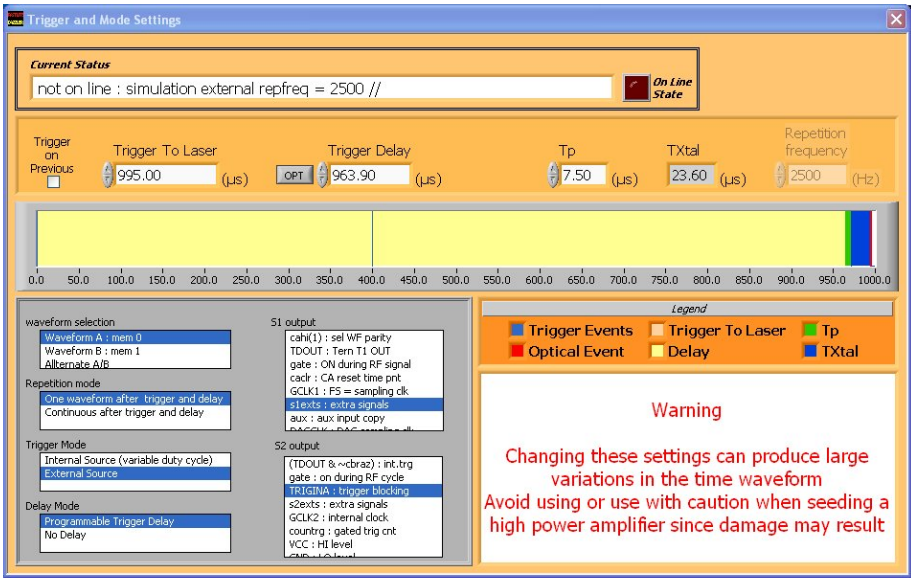


Figure 2.2: Example of correct setup.

7. Press the `OPT` button: the software will then compute the exact required delay to optimize the synchronization between the acoustic and optical waves.

8. Close the `Trig and mode` panel.

Coarse pulse compression

1. Press the `LOAD` (launch acoustic wave) button in the blue area.

2. Check that "A : mem 0" is selected on the display mode selector in the machine control area.

3. Check that the host LED of the RF generator pulses more rapidly for a short time after the button is pressed. The RF_ON Led will be lit if power is above 12%.

4. Check that a waveform appears in the left hand side display of the "Loaded Waveform" display (right-hand top corner of the Dazzler software window).

Once this is done, the pulses are ready to be amplified. Before going to the next step, the amplified pulses must be compressed. Some basic nonlinear effects (SHG, continuum generation in air...) or simple pulse characterization devices (single-shot autocorrelator...) must be used at this point to optimize roughly the pulse compression.

2.3 DazScope setup

2.3.1 Hardware

The DazScope hardware is the simplest hardware for pulse characterization. It consists of a lens focusing the beam onto a second harmonic generator (typically a 20μm BBO crystal), a refocussing lens and a high-resolution spectrometer (read through a USB link). This optical part is directly

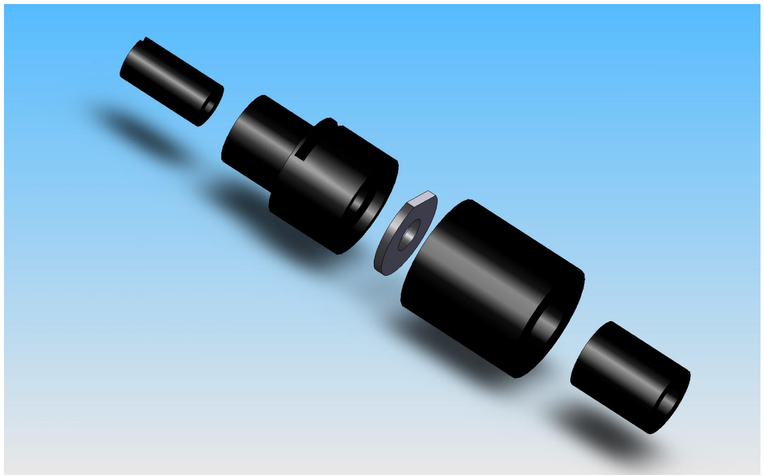


Figure 2.3: Assembling the optical module of the DazScope

Repetition rate	Focusing lens	Fluence per pulse
10Hz	no	0.1-1mJ/cm^2
10Hz	yes	0.1-1μJ/cm^2
kHz	no	30-300μJ/cm^2
kHz	yes	30-300nJ/cm^2

Table 2.1: Recommended operating conditions.

mounted onto the spectrometer and looks like an objective, as shown in the figure 2.3. Depending on the incident pulse intensity, the first focusing lens may be removed.
The alignment of the system only requires to optimize the blue generation by properly focussing the beam onto the non linear crystal. Please be aware of dispersion artifacts that can occur at the focal spot depending on spatial and spatio-temporal quality of the beam. For a large beam, pay particular attention to the "edge" effects of the lens which has a 25mm focal length. For very short pulses (<50fs) it is easier to send directly the beam unfocussed onto the non linear crystal. A blue filter is supplied with the DazScope: it can be inserted after the nonlinear crystal and might be useful to attenuate residual fundamental light.

A cable is supplied to trigger the spectrometer at a suitable repetition rate. The trigger signal must be a TTL 0-5V pulse. Various trigger and acquisition options can be chosen from the DazScope software in the spectrometer configuration panel.

Connect the spectrometer to the computer via the A-B USB cable (a green LED lights up on the front panel of the spectrometer) and connect the Dazzler RF generator to the *same* computer[8].

2.3.2 Alignment

Before starting the DazScope software, please be sure that the USB dongle provided with the DazScope CD-ROM is plugged in the computer. Start the Dazzler software and in the `setup` menu, check `remote enable`. Check that the Dazzler is correctly triggered. Eventually, start the

[8]Remote connection though a network is also possible - contact info@fastlite.com for more information.

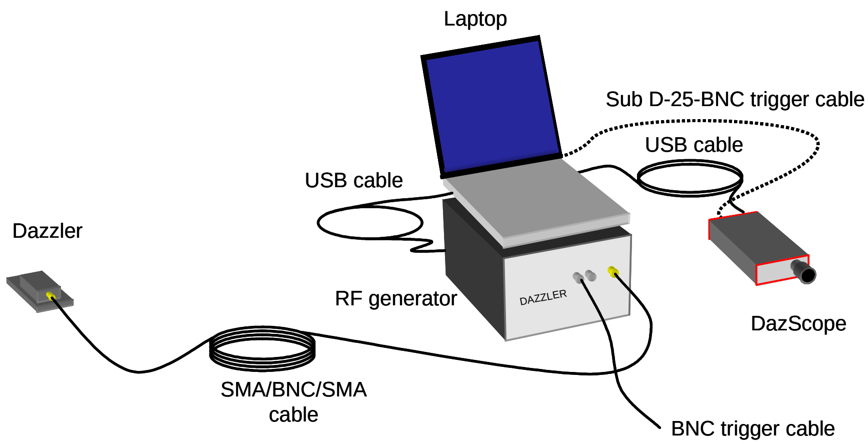


Figure 2.4: Wiring sketch. The power supply cable of the RF generator are not shown.

DazScope software.

In the `Spectrometer` menu, select `Configure...` and configure the acquisition parameters of the spectrometer: wavelength range of interest, trigger mode, integration time and number of averages per spectrum. Close the panel, select the `Spectrum` in the algorithm listbox, click on the `Run` button and tweak the input beam direction until the SHG spectral intensity is maximized. Tweak then integration time, and Dazzler diffracted power in order to get typically $\sim$ 10000 counts at maximum in the spectrum.

If no second harmonic spectrum is found...

If the spectrometer has an octave spanning spectral range (e.g. the spectral range of the spectrometer is 350-900nm):

1. Uncheck the `Run` button
2. Remove the blue filter
3. In the `Spectrometer` menu, go to `Configure Spectrometer...` and change the spectral range so that the fundamental spectrum can be displayed
4. Check the `Run` button
5. Tweak the input beam direction to maximize the signal
6. Go back to the initial configuration: the SHG signal shouldn't be difficult to find from here

If the spectrometer works on the second order of diffraction (e.g. the spectral range of the spectrometer is 700-900nm):

1. Uncheck the `Run` button
2. Remove the blue filter
3. Check the `Run` button

4. Tweak the input beam direction to maximize the signal
5. Go back to the initial configuration: the SHG signal shouldn't be far

CHAPTER

3

SOFTWARE OVERVIEW

The main part of the DazScope system is an elaborate software that remotely controls the Dazzler pulse shaper to optimize the spectral phase (i.e. make it linear with frequency).

3.1 Quick start

This section gives a rapid overview to be able to carry a first optimization as explained in the next chapter.

At startup, an initialization window of the spectrometer opens (figure 3.1). If the spectrometer is not connected, the software will automatically switch to the simulation mode. Otherwise, the spectrometer reference number will be displayed in the initialization window.

The spectrometer settings can be modified by clicking on the `Spectrometer` menu and selecting the `Configure` item. This will open a configuration window (figure 3.2). Adjust the spectral range to the spectral width of the pulses to be characterized[1]. When the `Advanced Mode` checkbox is checked, an extended window appears. The trigger settings can be modified from this window. When finished, click on ok.

The SHG spectrum can now be recorded directly from the main window: select the `Spectrum` item in the algorithm list and click on the run button. The recorded spectrum is shown in the top graph. A chart of past SHG levels is displayed in the bottom figure. Optimize the second harmonic spectrum level by properly aligning the optical setup. To stop the spectrum measurement click on the `Run` button once again.

Then start the first optimization: select the `ChirpScan` item in the `Algorithm` list and click on `Run`

At the end of each chirp scan, a window indicating the result of the measurement will appear.

[1]Three to four times the FWHM spectral width is a good rule of thumb.

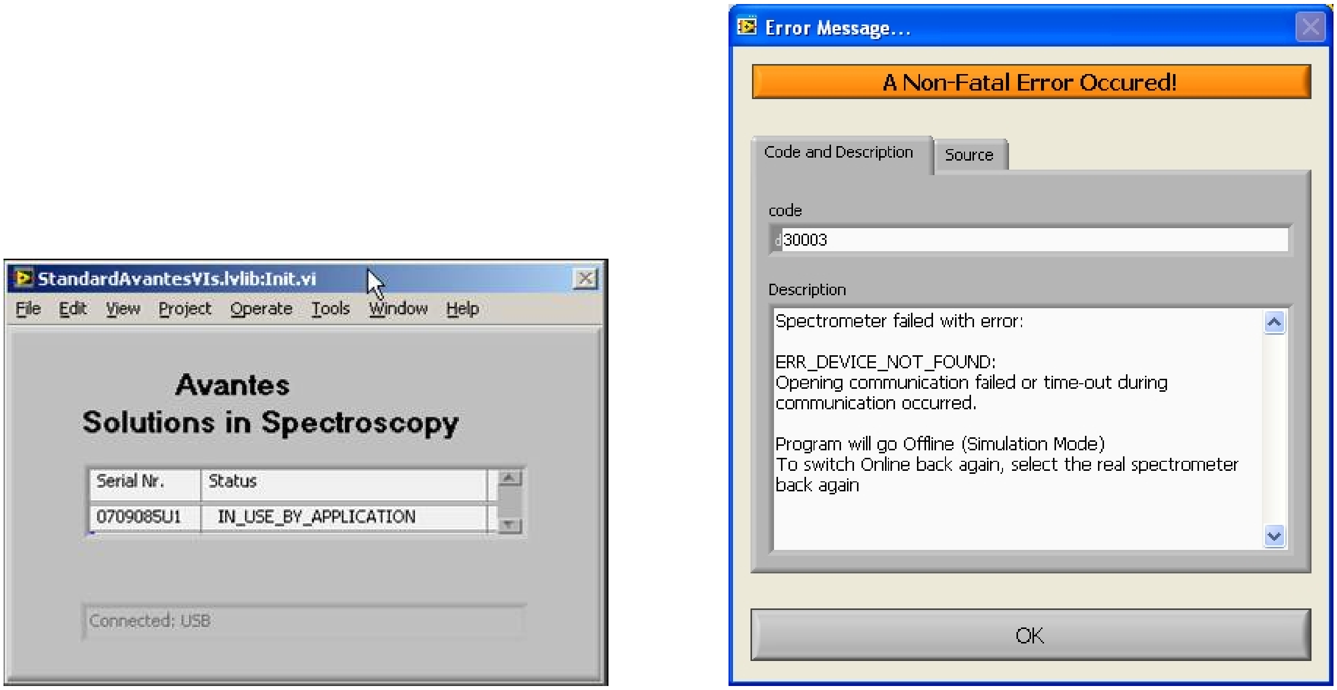


Figure 3.1: Spectrometer initialization windows.

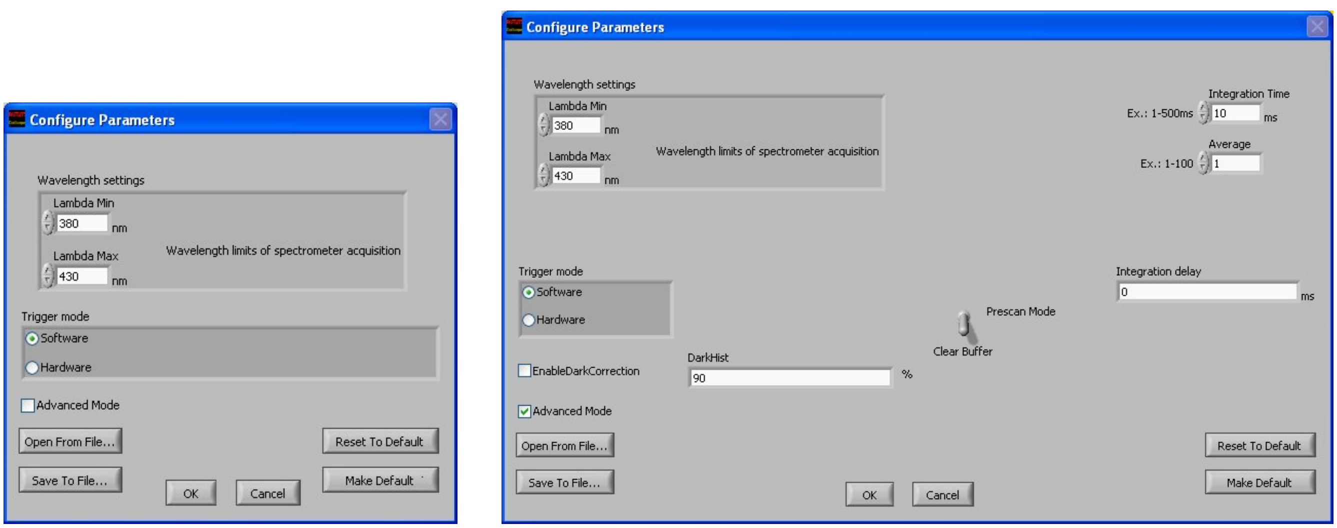


Figure 3.2: Spectrometer configuration window. Left: simplified panel. Right: advanced panel.

3.2 Software description

The DazScope front panel contains three distinct areas (figure 3.3):

- the menu bar
- the control area (the yellow area)
- the display area (two display areas)

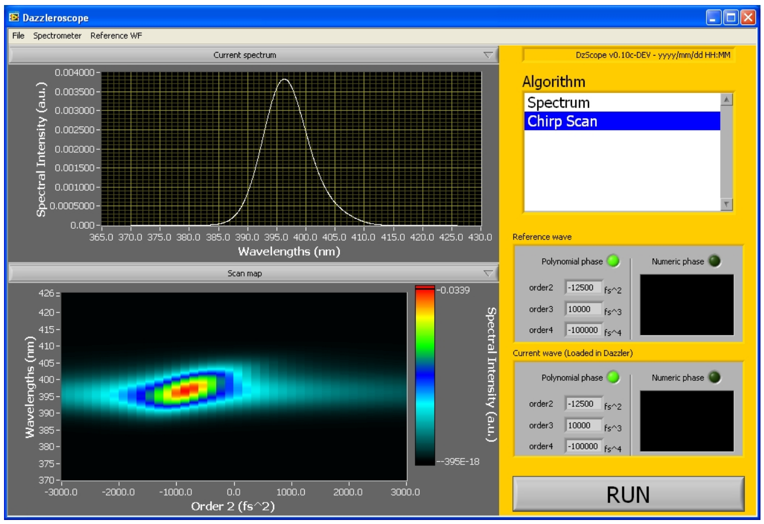


Figure 3.3: ChirpScan acquisition.

3.2.1 Menu bar

File menu

From this menu the current experimental results can be saved to a proprietary file format. The user can also launch a data browser software to read the previously saved files and export the experimental data and/or experimental parameters to ASCII and XML files.

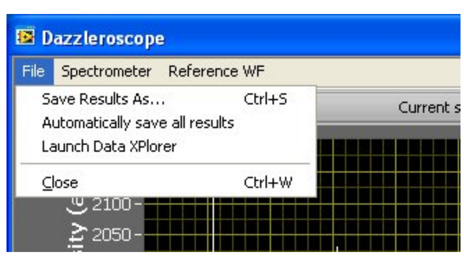


Figure 3.4: Content of the "File" menu.

Save Measurement Results as... : saves the last completely acquired data to a binary file format.

Automatically save all results: when used, this option will save all the acquired data in a specific folder.

Launch Measurement Results Xplorer... : opens the corresponding software in a new window.

Close: closes the DazScope software.

Spectrometer menu

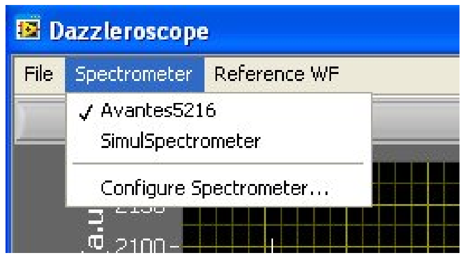


Figure 3.5: Content of the "Spectrometer" menu.

This menu is divided in two parts : a list of all available spectrometers and a link to the configuration panel of the active spectrometer. The active spectrometer is indicated by a check symbol in the spectrometer list.

3.2.2 Control area

This area contains all the implemented measurements and/or algorithms and a the `RUN` button. To date there are only two possible "algorithm": `Spectrum`, which is just a live record of the SHG spectrum and `ChirpScan` which is a phase optimization algorithm. To launch one of these two actions, the user must first select the appropriate item in the algorithm list and then press the `RUN` button. To stop the algorithm while running, uncheck this button.

3.2.3 Display area

This area displays the name of the current measurement and the experimental data.

3.3 Setting up a measurement

3.3.1 Configuring the spectrometer

From the menu bar, select the `Spectrometer` menu and click on the `Configure spectrometer...` item. This launches a window displaying the currently used parameters. Depending on the spectrometer model, several parameters can be set and displayed. If the `Advanced` checkbox is checked, all the spectrometer parameters and options are displayed. When this checkbox is unchecked, the software displays only a minimal set of parameters.

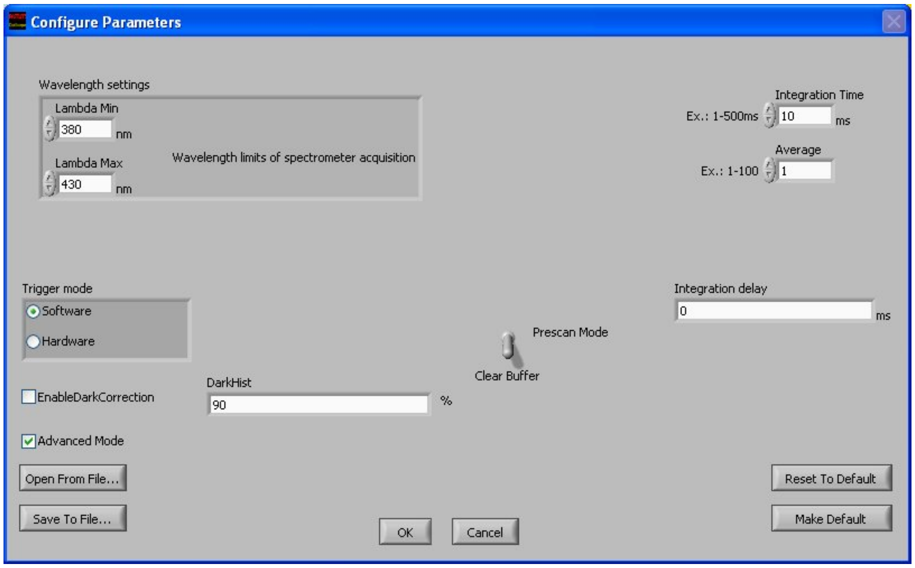


Figure 3.6: Content of the spectrometer configuration panel.

Integration time: integration time of the spectrometer expressed in the units indicated on the right on the numeric control.

Average: number of spectra to acquire for a given acoustic wave. The displayed spectrum is the average of all acquired spectra.

Lambda Min: lowest wavelength to acquire (expressed in the units specified on the right side of the numeric control)

Lambda Max: highest wavelength to acquire (expressed in the units specified on the right side of the numeric control)

Open From File...: loads the parameters from an XML file.

Save To File... : save the current parameters to an XML file.

Reset To Default: resets the parameters to their default values.

Make Default: sets the current parameters as default parameters.

3.3.2 Configuring the ChirpScan algorithm

Double-click on the `ChirpScan` item of the `Algorithm` listbox. The configuration panel of the ChirpScan panel opens (figure 3.7).

During the chirp scan successive waveforms are defined and sent into the Dazzler and the corresponding SHG spectra are recorded and displayed. All waveforms are strictly identical, but for the chirp value which is scanned over a given interval. This interval is defined as a variation

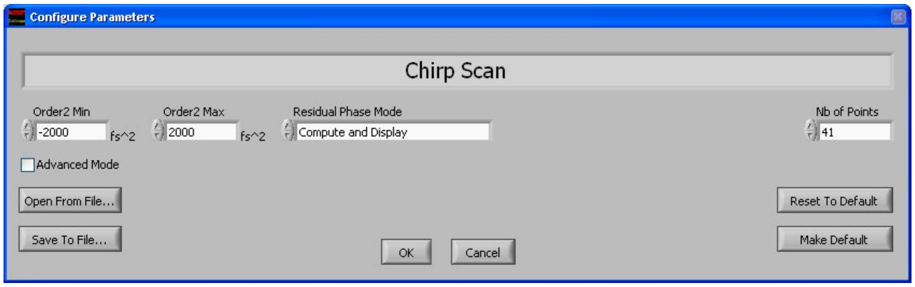


Figure 3.7: Content of the ChirpScan configuration panel (simplified panel).

Pulse bandwidth (nm)	Order 2 min (fs^2)	Order 2 max (fs^2)
10	-20 000	+20 000
20	-5 000	+5 000
30	-3 000	+3 000
40	-2 000	+2 000
50	-2 000	+2 000
60	-2 000	+2 000

Table 3.1: Recommended minimum values for the ChirpScan algorithm as a function of the amplified pulse bandwidth at 800nm. A rule of thumb is to choose 2 or 3 times the square of the FWHM duration of the corresponding Fourier-transform-limited pulse. Larger values may be used if the spectral phase to correct for is particularly high.

around the current reference waveform `order2` (see subsection 3.3.3). More precisely the scanned second orders are given by formula 3.1:

$$\varphi_{2,k} = \varphi_{2,\mathrm{ref}} + \varphi_{2,\mathrm{min}} + (\varphi_{2,\mathrm{max}} - \varphi_{2,\mathrm{min}})\,(k-1)/(N-1) \text{ for } k = 1..N \tag{3.1}$$

where $\varphi_{2,\mathrm{ref}}$ is the second order phase coefficient of the reference waveform, $\varphi_{2,\mathrm{min}}$ is the value of the `Order2 Min` control and $\varphi_{2,\mathrm{max}}$ is the value of the `Order2 Max` control. `N` is the number of discrete chirp values scanned over the range defined by the former second order values. Units are in fs^2.

Some optional settings of the ChirpScan algorithm can also be defined. The ChirpScan algorithm was basically specified and designed to correct polynomial spectral phase up to the fourth order only. However, it has, in principle, the ability to detect more complex phase aberrations. The measured spectral phase is therefore divided into:

- a fourth order polynomial phase
- a residual phase

Depending on the settings of the ChirpScan algorithm, the DazScope can correct for either the polynomial phase only or the full spectral phase.

Residual phase mode: indicates which curves are displayed on top of the experimental data picture and if the user is allowed to correct for the residual phase.

- Do not correct: displays only the polynomial correction (white curve). No residual phase correction allowed.

- Compute only: same as "Do not correct". No residual phase correction allowed. For debugging purposes only.
- Compute and Display: displays both the measured local second order phase (white curve) and the polynomial correction (black curve). No residual phase correction allowed.
- Compute, Display and Ask to Apply: displays both the measured phase function (white curve) and the polynomial correction (black curve), enables to ge beyond the polynomial correction.

Recommended mode is "Compute and Display".

Mean filter half width (Advanced): this option allows to smooth the measured SHG spectra before running the ChirpScan algorithm.

Threshold (%) (Advanced): Experimental data points under this threshold value (expressed in fraction of the experimental maximum count number) are ignored by the ChirpScan algorithm. *Recommended value is 10-30% depending on the signal-to-noise ratio.*

3.3.3 Editing the reference waveform

From the menu bar, select the `Reference WF` menu and the `Edit current Ref.WF...` item. This opens a window displaying the current reference waveform. In the DazScope, the reference waveform refers to the acoustic wave used when no optimizing algorithm is running. It is the waveform displayed on the Dazzler panel when the `Spectrum` measurement is running. THE USER MUST BE AWARE THAT WHEN THE DAZSCOPE SOFTWARE STARTS, THE REFERENCE WAVEFORM IS LOADED FROM A CONFIGURATION FILE WHICH IS DIFFERENT FROM THE ONE USED BY THE DAZZLER SOFTWARE. WHAT IS MORE, MODIFICATIONS OF THE FRONT PANEL OF THE DAZZLER SOFTWARE WILL NOT AFFECT THE REFERENCE WAVEFORM. THE REFERENCE WAVEFORM CAN ONLY BE EDITED THROUGH THE DAZSCOPE SOFTWARE "REF. WF" MENU.

WaveForm name: customizable name of the waveform.

Amplitude mode: defines how the modulus of the complex transfer function of the Dazzler (referred to as amplitude) is calculated. If several boxes are selected the amplitude is equal to the *product* of each individually defined amplitude functions.

- Dials: supergaussian or gaussian function defined by the displayed dials.
- Formula (Advanced mode): analytical formula.
- Numerical Amp: ASCII text file.

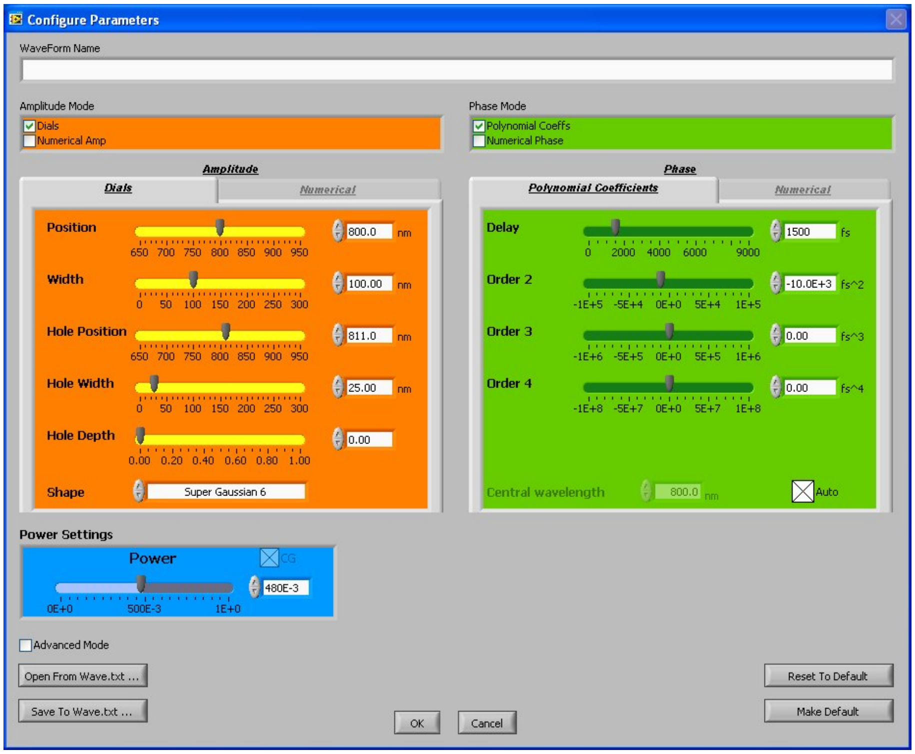


Figure 3.8: Content of the reference waveform configuration panel.

Phase mode: defines how the phase of the complex transfer function of the Dazzler (referred to as phase) is calculated. If several boxes are selected the phase is equal to the *sum* of each individually defined phase functions.

- Dials: fourth order *Taylor expansion* around the wavelength given by the `central wavelength` control if `auto`=0 or by the `position` control if `auto`=0 .
- Formula (Advanced mode): analytical formula.
- Numerical Amp: ASCII text file.

Please refer to the Dazzler manual for the description of the controls displayed in the `Dials` panels, as well as for the `Power Settings`.
In the advanced mode, the panels slightly change. Please contact Fastlite for a complete description of the extended controls (especially for the formulae). Switching to the advanced mode also displays the `Security Settings` sub-panel (see figure 3.9). To prevent the user and/or the optimizing

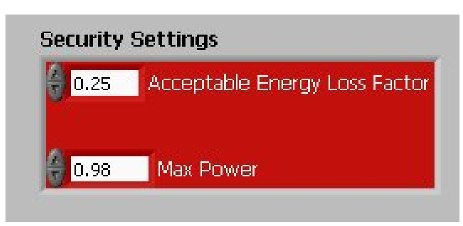


Figure 3.9: Content of the "Security Settings" area (advanced panel).

algorithm from sending a dangerous waveform[2] into the Dazzler and the laser chain, the software checks that every waveform to be loaded is safe, which means:

- the waveform lies in the pulse shaping capability of the Dazzler.
- the diffraction efficiency stays within a safe range.

Two parameters are involved in the security settings.

Acceptable Energy Loss Factor: maximum fraction (0-1) of the acoustic energy that can be "out of the crystal".

Max power: maximum power level.
The user is strongly recommended to leave the default values unchanged.

3.3.4 Selecting and starting a measurement

To set a measurement from the loaded measurements list, select the corresponding item in the `Algorithm` listbox located in the control area and press `Run`. This updates the display area and opens the related data processing software.

[2] a truncated waveform for example.

CHAPTER

4

OPTIMIZING THE PULSE DURATION USING CHIRPSCAN

4.1 Optimization

Once the ChirpScan algorithm is started, the software acquires several spectra and displays all the acquired spectra in a 2D map (see figure 4.1). A dialog panel then pops up and prompts the user to proceed to the next step which can either be:

- keep the current waveform without any modifications (`Keep Ref.WF as is`.)
- compensate for the measured spectral phase (`Apply these corrections to Ref.WF`).

By selecting one or several check boxes, the user can choose to correct for any combinations of second, third and fourth orders. The corresponding values of phase coefficients are displayed. The central wavelength with respect to which these coefficients are defined (Taylor expansion of the spectral phase) is also displayed as a reminder. The resulting correction is displayed on top of the 2D map and can be compared to the measured phase function (more precisely, to the second order derivative of the spectral phase). If the corresponding option was selected in the configuration panel of the ChirpScan algorithm, it is also possible to correct for the residual phase by selecting "Correct residual phase numerically".

At this point, the software leaves it to the user to check that the spectrometer did not saturate at any moment during the scan, i.e. all units are below the maximum count in the 2D scan map. In case this happens, the user is asked to press `Keep Ref.WF as is`, to adapt the input energy or adjust the integration time of the spectrometer and run the ChirpScan measurement again.

By clicking on the button labeled `Apply these corrections to Ref.WF`, a new reference waveform is computed based on the selected phase correction parameters and sent to the Dazzler. The ChirpScan algorithm can be run again to monitor the effects of the phase corrections and/or

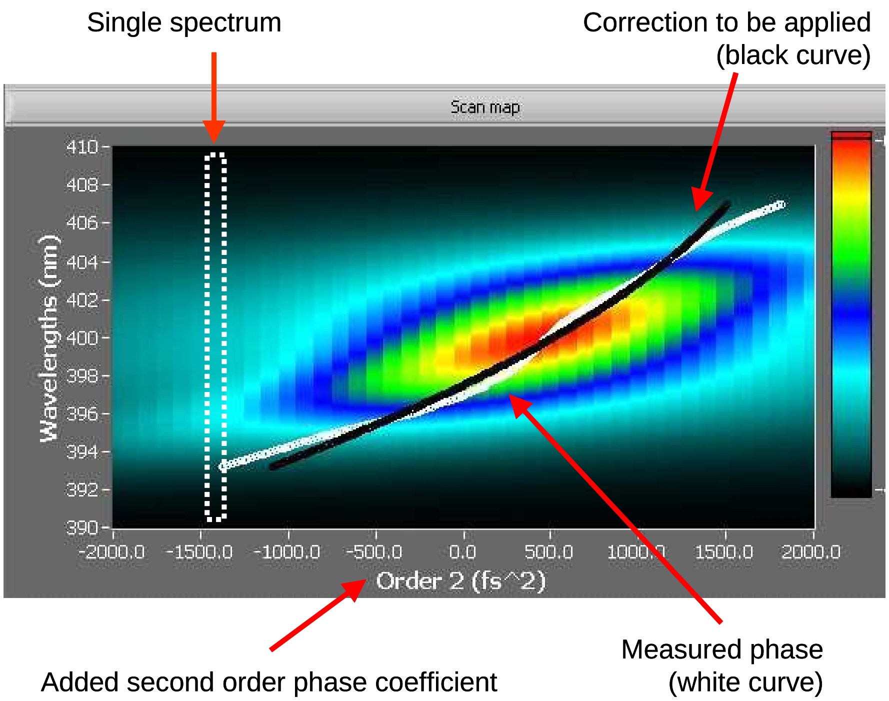


Figure 4.1: Displayed 2D map displayed at the end of the data acquisition.

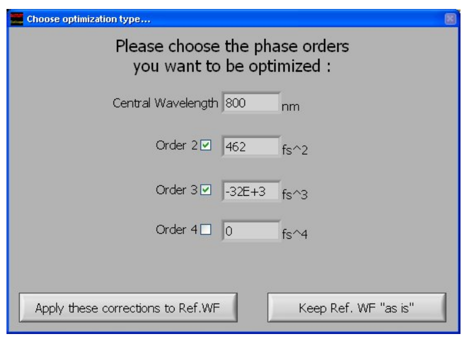


Figure 4.2: Displayed dialog panel displayed at the end of the data acquisition.

to measure and correct the spectral phase once again.

After a small number of iterations (typically <5), the spectral phase should be flattened and ChirpScan experimental maps should converge toward a map exhibiting the following features :

- maximum values are reached when the added second order is almost zero.
- the map is symmetric with respect to the second order axis (left-right symmetry).

If these two criteria are not met, there is still some residual spectral phase to correct for.

4.2 When to stop?

As the phase corrections are expressed in terms of phase coefficients, it is not straightforward to evaluate how big the corrections are or might be. Table 4.1 gives some typical values for the first

Pulse bandwidth @800nm	Pulse duration	Order 2	Order 3	Order 4
10nm	94fs	$5\,500\text{fs}^2$	$1\,000\,000\text{fs}^3$	$250\,000\,000\text{fs}^4$
20nm	47fs	$1\,400\text{fs}^2$	$100\,000\text{fs}^3$	$17\,000\,000\text{fs}^4$
30nm	31fs	600fs^2	$36\,000\text{fs}^3$	$2\,500\,000\text{fs}^4$
40nm	24fs	350fs^2	$15\,000\text{fs}^3$	$900\,000\text{fs}^4$
50nm	19fs 220fs^2	$8\,000\text{fs}^3$	$300\,000\text{fs}^4$	
60nm	16fs 150fs^2	$4\,900\text{fs}^3$	$190\,000\text{fs}^4$	

Table 4.1: Phase coefficients values that causes a doubling of the (TF limited) pulse duration, as a function of bandwidth at 800nm for a gaussian spectrum.

Pulse bandwidth @800nm	Order 2 (gaussian)	Order 2 (flat-top)
10nm	$1\,000\text{fs}^2$	$7\,000\text{fs}^2$
20nm	250fs^2	$1\,700\text{fs}^2$
30nm	100fs^2	750fs^2
40nm	60fs^2	450fs^2
50nm	40fs^2	275fs^2
60nm	30fs^2	185fs^2

Table 4.2: Order of magnitude of negligible phase coefficients values as a function of bandwidth at 800nm and as a function of the spectral shape.

four phase coefficients as a function of the bandwidth at 800nm. These values correspond to a pulse lengthening of about a factor of two with respect to the shortest achievable pulse duration for a gaussian pulse[1]. All pulse durations and bandwidths are FWHM values. For non-gaussian pulses, the phase coefficient values must be multiplied by a factor depending on the exact spectral shape. For a supergaussian of order 6, this factor is about 3-4.

Another point of interest is the value of second order for which the change in time domain is negligible. The second orders corresponding to a broadening of 5% in the FWHM intensity pulse duration can be found in table 4.2 for both gaussian and supergaussian (flat top) spectra.

When the measured second order derivative of the phase displayed at the end of a chirp scan lies within a small vertical extent of added second order (this extent strongly depends on the bandwidth and exact shape of the spectrum as shown in table 4.2), the optimization is done and the pulse is compressed as best as possible.

[1]For orders 3 and 4, these values have been minored to take into account the extension of the pulse in the feet.

CHAPTER

5

THEORY

Most techniques for characterizing the phase of short pulses can be divided into three successive steps: a linear filter, a non linear interaction (e.g. SHG) and a spectral measurement of the output. In the case of Frequency Resolved Optical Gating (FROG), the linear filtering consists in generating two time-shifted replica of the original pulse. Since a significant number of CPA amplifiers now include a pulse shaper in their front-end, it is highly convenient to use such a device not only to correct but also to characterize the amplified pulses by adding at the back-end a nonlinear element and a spectral detector.

However, in this case, methods that rely on pulse replicas are not favoured since the corresponding pulse structure will not, in general, propagate in the amplifier without being strongly distorted (e.g. a train of pulses will be obtained instead of two pulses). On the contrary, techniques that use phase-only shaping produce only negligible non linear effects in a strongly chirped CPA amplifier.

In the ChirpScan method, we take advantage of the ability of the AOPDF to program pure accurate second order phase, to implement phase characterization, using few SHG spectra.

5.1 Principle

Applying the stationary phase theorem to the SHG process, one can show that the SHG spectrum $I_{\mathrm{SHG}}(2\omega)$ exhibits a maximum as a function of pulsation whenever $\varphi''(\omega) \simeq 0$. Furthermore, the same theorem states that for sufficiently chirped pulses the spectrum of the second harmonic $I_{\mathrm{SHG}}(2\omega)$ can be accurately described by the following expression:

$$I_{\mathrm{SHG}}(2\omega) \propto \frac{I^2(\omega)}{|\varphi''(\omega)|} \tag{5.1}$$

where $I(\omega)$ stands for the spectrum of the fundamental pulses and $\varphi''(\omega)$ for the second order derivative of the spectral phase of the fundamental pulse (i.e. the "local" chirp of the pulse).

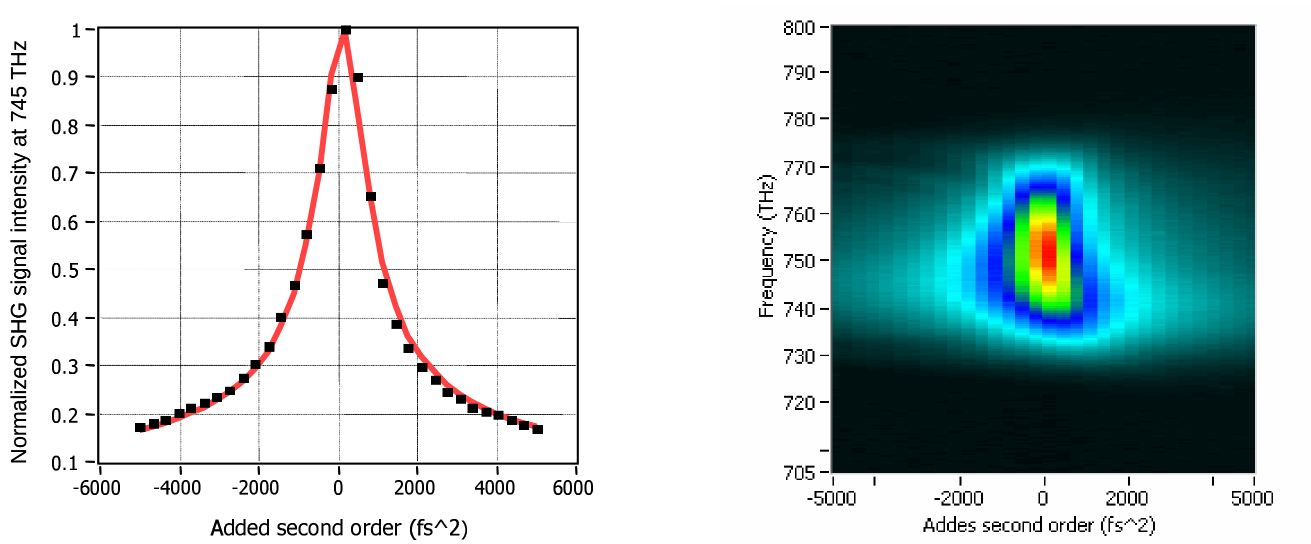


Figure 5.1: Left: map of SHG spectra as a function of frequency and added second order phase coefficient. Right: typical Lorentzian fit (dotted line) to the experimental data (solid line) at a given wavelength.

The validity of Equation 5.1 can be confirmed by recording the SHG spectrum of a near Fourier-transform limited pulse to which a purely parabolic phase $\phi_2 (\omega - \omega_0)^2 /2$ is added. In this case, the asymptotic expression of the SHG spectrum is a hyperbolic function of the second order phase coefficient ϕ_2 since the expected SHG spectrum is, according to Equation 5.1:

$$I_{\mathrm{SHG}}(2\omega) \propto \frac{I^2(\omega)}{|\phi_2|} \tag{5.2}$$

Figure 5.1 shows some typical experimental SHG signal recorded at a given pulsation as a function of a programmed second order phase coefficient introduced by an AOPDF pulse shaper. A Lorentzian fit confirms the validity of Equation 5.1, hyperbolic at large chirps.

Thanks to the asymptotic behavior of the SHG spectrum for high chirps, it is possible to retrieve analytically the second derivative of the spectral phase from only a few experimental measurements. For a given pulse of spectral phase $\varphi(\omega)$, we successively add to the pulse a ramp of frequency chirps of varying second order coefficients φ_2. For every value of φ_2, the SHG spectrum $I_{\mathrm{SHG}}(\omega, \varphi_2)$ is recorded. At the end of the acquisition, the software fits, for every measured pulsation, the experimental data $I_{\mathrm{SHG}}(\omega, \varphi_2)$ with a reference function and retrieves $\varphi''(\omega)$. An adequate weight function is used to ignore the values measured at small chirps, in order to fit only the hyperbolic decrease of the experimental data.

5.2 Examples

To illustrate the efficiency and accuracy of this method, we compare the SHG spectrum obtained for a chirp scan from $-3\,000\mathrm{fs}^2$ to $+3\,000\mathrm{fs}^2$ onto four different optical pulses:

- one Fourier transform (ie purely linear spectral phase) (Figure 5.2),
- one with a pure second order only $+1\,000\mathrm{fs}^2$ (Figure 5.3),

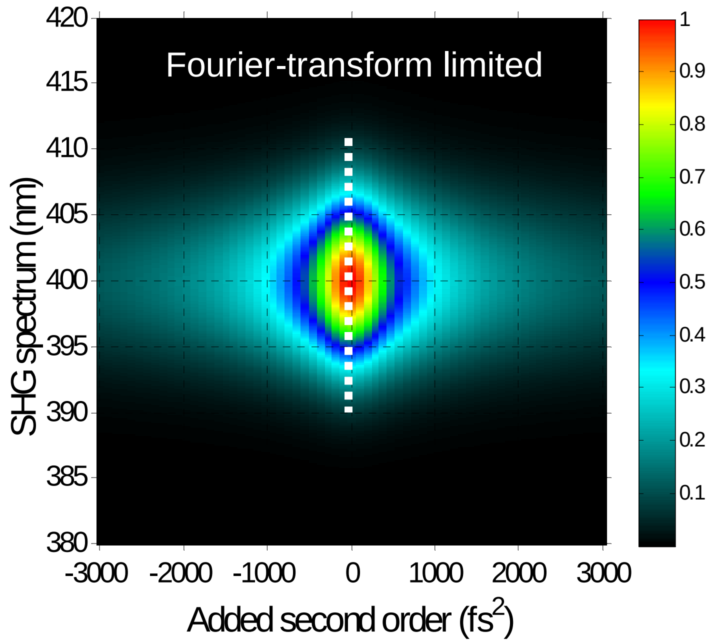


Figure 5.2: Chirp scan - Fourier transform limited case. White dots: second order derivative of the spectral phase as a function of wavelength.

- one with a pure third order only $+50\,000\text{fs}^3$ (Figure 5.4),
- one with a pure fourth order only $+2\,000\,000\text{fs}^4$ (Figure 5.5),
- one with a sinusoidal spectral phase (Figure 5.6).

For the first example of distorted pulse, a purely chirped pulse, the compensation of the spectral phase occurs for the same chirp value at every wavelength. So compared to the Fourier transform limited pulse, on the SHG spectra vs chirp image, it only shifts the image laterally. The value of the shift corresponds directly to the chirp. For the purely third order spectral phase pulse, as the local chirp in a 3rd order is linear, the image corresponds to a linear chirp optimization vs wavelength. For a more complex phase, the image is distorted but still corresponds for each wavelength to the chirp value that flatten the phase at this wavelength. The image looks like the second order phase value vs wavelength:

- 2nd order: lateral shift,
- 3rd order: linear spread,
- 4th order: horse shoe…

As for FROG the map image gives a good qualitative information about the phase. The quantitative value of the phase (more precisely of the second order derivative of the spectral phase) is determined by the estimation for each wavelength of the center of symmetry as the first order momentum:

The determination by the center of symmetry is robust to noise and requires very few points (11 points per scan is enough for optimization process). It is especially efficient on the wings of

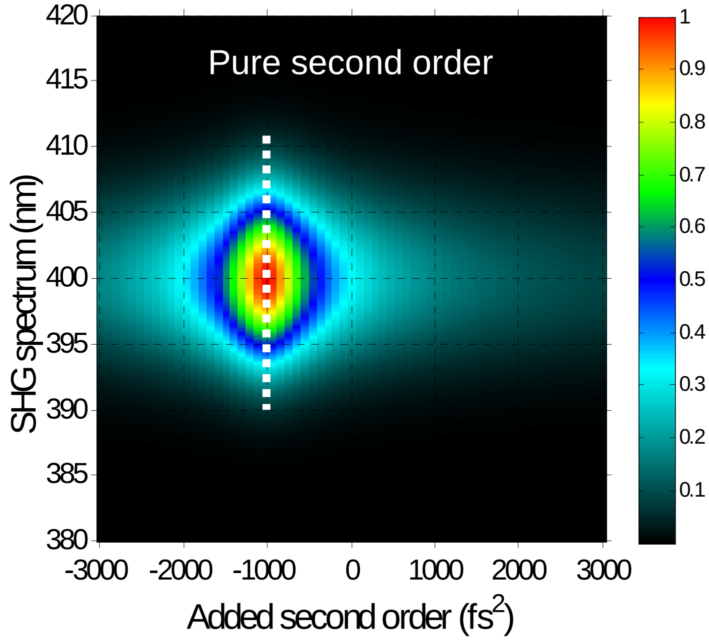


Figure 5.3: Chirp scan - pure second order phase. White dots: second order derivative of the spectral phase as a function of wavelength.

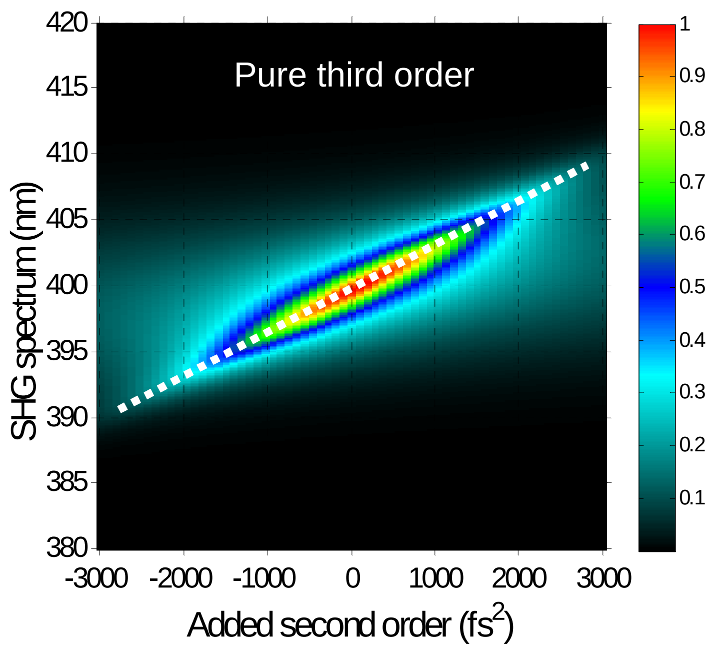


Figure 5.4: Chirp scan - pure third order phase. White dots: second order derivative of the spectral phase as a function of wavelength.

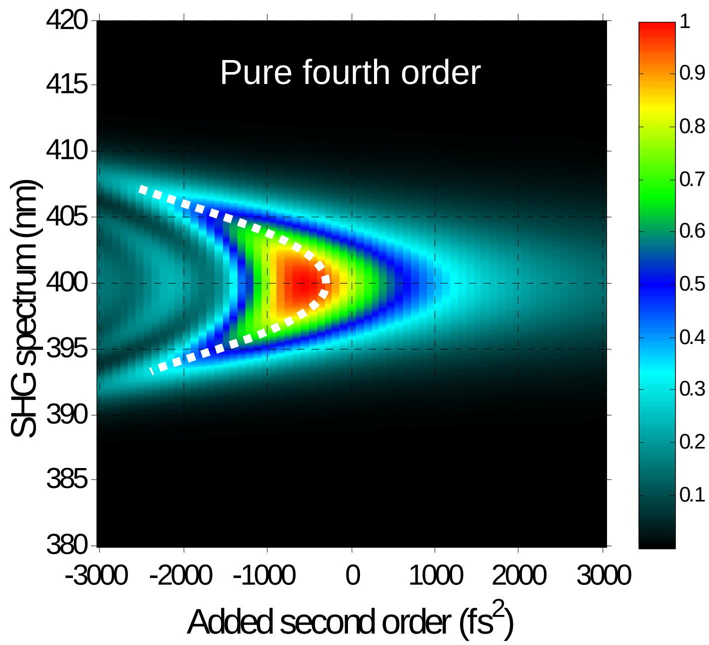


Figure 5.5: Chirp scan - pure fourth order phase. White dots: second order derivative of the spectral phase as a function of wavelength.

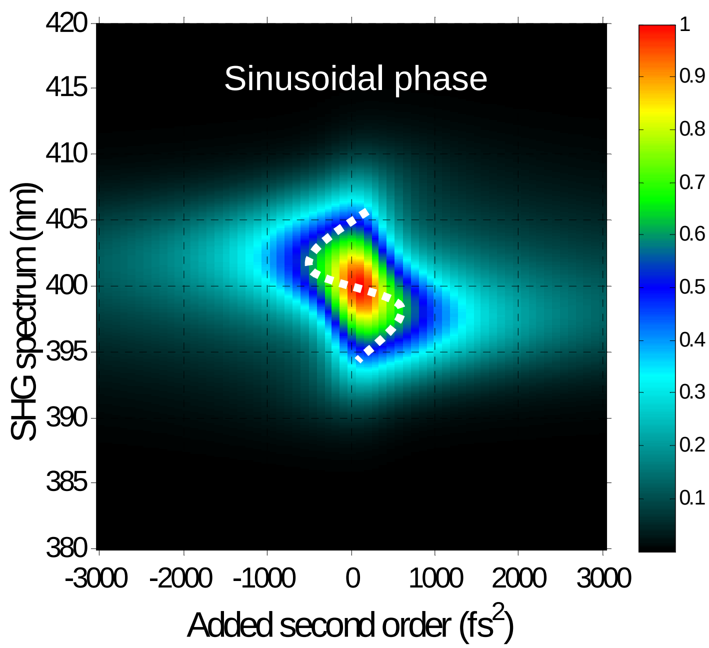


Figure 5.6: Chirp scan - sinus phase.

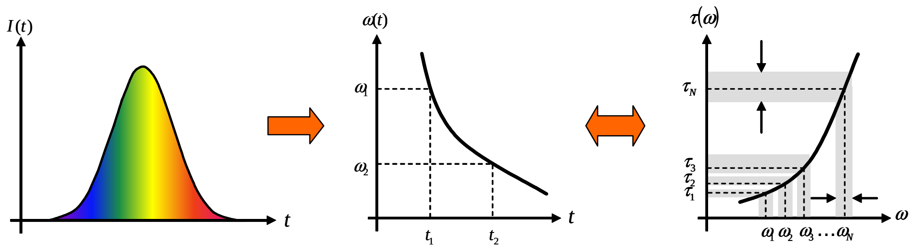


Figure 5.7: Description of a highly chirped pulse.

the spectrum where ultrashort pulse measurements usually lack precision. By using this principle we measure the phase or a part of the phase and reintroduce it into the pulse shaper to correct the phase. The goal is to obtain the image of the Fourier transform limited pulse, whose main characteristic is symmetry versus chirp value (see figure 5.2)

5.3 More about the key formula

Formula 5.1 can be derived very simply when one considers a highly chirped pulse and more generally for pulses fulfilling the two following conditions:

1. the group delay is monotonic with respect to frequency and, to first order, a linear function of frequency.
2. the pulse duration is much longer that its Fourier-transform limit.

Under these assumptions, a time-dependent frequency $\nu(t)$ can be defined and the pulse can be described as a succession of independent pulses of increasing or decreasing wavelengths with different pulse widths and different amplitudes (see figure 5.7). Because of the time-frequency uncertainty relationship ($\Delta t \Delta \nu \geq 1$), this decomposition is limited to a finite number of such independent sub-pulses, that is to say to a finite number of non overlapping sub-pulses in both time and spectral domains. *De facto*, this number is related to the second order derivative function of the spectral phase, *i.e.* to the local chirp $\varphi''(\omega)$. Indeed, around a given pulsation ω_k, the group delay can be approximated by the following Taylor expansion:

$$\tau(\omega) = \tau(\omega_k) + \varphi''(\omega_k)(\omega - \omega_k)$$

As a consequence, the pulse duration of a sub-pulse of central wavelength ω_k and of spectral width $\delta\omega_k$ is:

$$\delta\tau_k = \varphi''(\omega_k)\delta\omega_k$$

However, this approximation breaks for small enough spectral widths since the time-frequency uncertainty relationship forces $\delta\tau_k \delta\omega_k \geq 1$. The mimimum time and spectral widths of the sub-pulse of pulsation ω_k are therefore:

$$\delta\tau_k \sim \sqrt{|\varphi''(\omega_k)|} \text{ and } \delta\omega_k \sim 1/\sqrt{|\varphi''(\omega_k)|}$$

This sets a maximum number of all possible time and spectrally independent and successive sub-pulses. For a purely chirped pulse ($\varphi''(\omega) = cte$), this maximum number if equal to the full spectral width multiplied by the square root of the chirp coefficient.

We now consider a decomposition of the pulse into a sequence of sub-pulses of equal spectral widths $\delta\omega$. This spectral width is chosen to be compatible with the results derived in the last paragraph, which is possible since the chirp function $\varphi''(\omega)$ is assumed to be constant at first order. Since these sub-pulses are separated in the time-domain, they undergo the process of second harmonic generation (SHG) independently. As the SHG conversion efficiency scales with the square of the instantaneous time-intensity, the SHG conversion efficiency of the sub-pulse k is proportional to:

$$\eta_k \propto \left(\frac{E_k}{\delta\tau_k}\right)^2$$

where E_k stands for the energy of the k-th sub-pulse, which is, to the first order, equal to $I(\omega_k)\delta\omega$. The SHG efficiency of the k-th sub-pulse is therefore proportional to:

$$\frac{I^2(\omega_k)}{|\varphi''(\omega_k)|}$$

The k-th sub-pulse being a narrowband pulse of pulsation ω_k, its contribution to the global SHG signal is only located around $2\omega_k$. As a result, $I_{\mathrm{SHG}}(\omega)$ can be described by the formula (5.1):

$$I_{\mathrm{SHG}}(\omega) \propto \frac{I^2(\omega)}{|\varphi''(\omega)|}$$

This result can be derived more rigorously by using the stationary phase approximation theory.

APPENDIX

A

DAZZLER INSTALLATION / UPGRADE

A.1 Purpose

The Dazzler™ application software is updated to correct errors, to provide more functionalities, to support upgraded hardware equipment and to follow the rapid changes in computing equipment. This describes the upgrading of the application software, as well as a complete installation on a different computer.

NB:

a) in the following, CDROM: indicates the drive letter of the CD drive where the FASTLITE software CD has been inserted,

b) this note applies only for the CD delivered with an "Installers" directory, earlier distributions were operating differently.

A.2 Principles

The components of the Dazzler software system are listed below, indicating their origin:

models	component	source
all	driver for the USB to serial line adapter	Keyspan™
all	LabView run-time support	National Instruments™
T2	driver for the USB to GPIB bus adapter	National Instruments™
T2	IEEE-488-2 run-time support	National Instruments™
all	Dazzler application software	FASTLITE™
all	Various utilities IrfanView, Acrobat Reader, ..	freeware

Warnings:

FASTLITE *does not guarantee the installation on another computer than the one delivered with the Dazzler system. However,* FASTLITE *will endeavour to help with that installation whenever possible.*

FASTLITE *will only help with the installation of non* FASTLITE *software provided that this external software is necessary to operate the Dazzler system.*

FASTLITE *will not guarantee operation if the original operating system has been tampered with, or its parameters modified*[1]

A.3 Actions

A.3.1 Keyspan™ driver

The **only** reason to reinstall this driver is when re-installing from scratch. Various Keyspan adapters have been shipped in the previous years. One should ask FASTLITE which adapter has been fitted in the generator. Systems from n°18 to n°83 use the USA19QW, systems after n°84 use the USA19HS, but better check with FASTLITE.

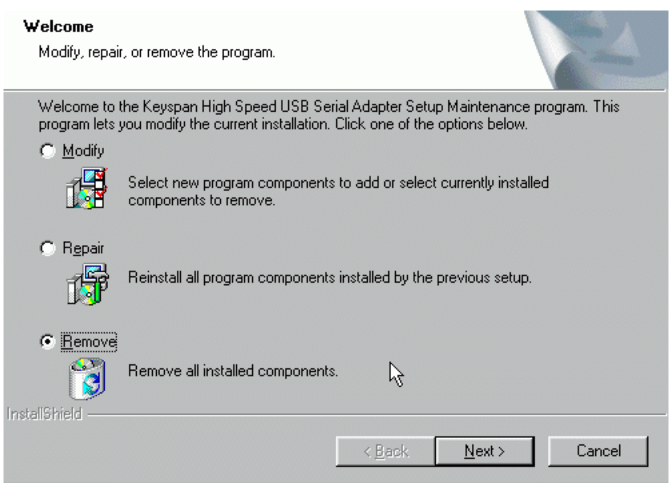
- USA19HS:

  CDROM:/Utilities&Drivers/USB/Keyspan-HS/KeyspanUSA19hsWinV34.exe

- USA19QW:

  CDROM:/Utilities&Drivers/USB/Keyspan-W-and-QW/KeyspanUSA19wWinV31.exe

  perform a *remove* action if the driver was previously installed. Make sure to restart the PC with the **USB cable unplugged**. Then, executing the same file `KeyspanUSA19wWinV31.exe` will perform the installation without any option. When that installation is complete, plug the Dazzler USB cable on **each** USB port of the PC, and wait long enough for Windows to install the 3 related drivers.



A.3.2 LabView™ run-time support

The application programs are written in LabView[2]. They require the LabView "run-time" to be installed. This is normally done before the system is shipped from factory, but there are two cases

[1] For instance, the "regional settings" should always define the decimal separator as the dot.

[2] Registered by National Instruments

for the user to need perform this installation: 1) complete re-installation of the PC, 2) whenever FASTLITE had to upgrade to a different release of LabView[3].

The LabView "run-time" is installed by executing the file
CDROM:/Installers/runtime-6.1/SETUP.EXE or the file
CDROM:/Installers/runtime-8.2/LabVIEW_8.2_Runtime_Engine.exe

Note that **several** versions of the "run-time" can coexist on the same system, hence one may operate older versions of the Dazzler software when trying out a new version.

A.3.3 GPIB driver and IEEE-488-2 support

This applies only to T2 models. The original CD from National Instruments is part of the delivery. The installation instructions must be followed carefully. Make sure to plug the GPIB adapter on **each** USB port and wait long enough for the installation of the driver files by & inside Windows, and of course, answer Yes to accept the installation. The "Measurement & Automation" tool from National Instruments should be used to test the presence of the GPIB adapter and its proper operation.

A.3.4 Utilities

These freeware have been found useful and reside on the CD under `Utilities&Drivers`. They are installed simply by executing the installation package file for each one required. A brief discussion of these tools follows:

- Acrobat Reader[4]: necessary tool for reading PDF files.
- IrfanView: a convenient free tool to capture "screen windows" and save them as files in different file formats.
- Izarc: a convenient tool to operate on ZIP archives.

These tools may be replaced by any other suitable tools that perform the same functions.

A.3.5 Dazzler application software

There are several operations to perform in the order prescribed. The "installer packets" are found in CDROM:/Installers

1. if there was a previous version installed, you may wish to keep it, or you may remove it. Recent installations have an "uninstaller" (in the program group).
2. installation of the application program: `setup-V400a-exe.exe` where the name will vary with the different releases. The CD may have several releases, be sure to liaise with FASTLITE to know which version is suitable for your system. By default, executing the file, will define a directory where the executable files and working files will be installed. A program group Dazzler will be created, and icons will be deposited on the desktop. An icon will be created on the desktop pointing to the directory where the files are installed, by default this is `C:/Program Files/Dazzler`.

[3]Until version V324L included, FASTLITE was using French LabView release 5.1. From version V324M, the US Labview release 6.1 has been used up to version V400, later releases use US LabView 8.2.

[4]Registered by Adobe.

3. installation of the current manual: `setup-manual.exe`
4. installation of the examples and remote library: `setup-examples.exe`
5. indicating to the newly installed executables where to find the parameter files, described in the note describing the parameters.
6. adjusting the remote path: press the "Set Path" button (see Figure A.1), this will modify the file `C:/dazzler/path.txt` which tells the remote applications where resides the Dazzler program.
7. setting the serial line COM port, refer to the note m04-COMS.

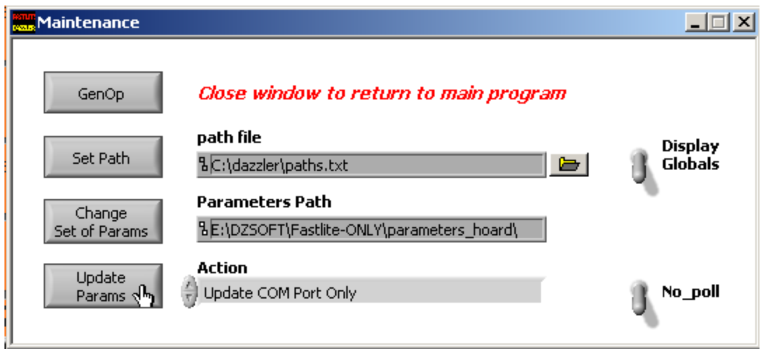


Figure A.1: Maintenance Window

A.4 E-mail reports

In case of any problem, please, get in touch via e-mail with as much information as possible in "computer ready format" at the address: `info@fastlite.com`

A.4.1 Screen captures

For screen captures, start Irfanview, select Options, then Capture, use defaults. Switch back to the window to be captured (clic into it to bring it to the forefront), and press control+F11. Save the captured file using the PNG format, most appropriate for screen dumps.

A.4.2 Parameters

In case your parameters have been lost, you might find a useful set on the CD-ROM under CDROM:/Fastlite-ONLY/parameters_hoard. The system reference appears on the back of the generator, just under the exhaust fan grille.

APPENDIX

B

DAZZLER PARAMETERS

B.1 Purpose

The Dazzler™ application software uses text files to keep data related to the complete system, like the crystal parameters, T2 option, etc. These parameters allow also to drive different models of RF generators with the same application. In principle, the user should NOT modify these files. He may however have to do so when adapting to a new release, or installing on another computer: these changes should always be done in consultation with Fastlite.

B.2 Parameters Files

B.2.1 Location and Names of Files

Parameters files are generally kept in a different directory than the Dazzler™ software itself. This allows to store them on a different partition than the system. The location of that directory is defined in the file "`<Dazzler Software Directory>/params.txt`". One should find here a line of the form :

```
D  <generator SN>  <Parameters Directory Path>
```

The location of that directory can be changed : see section B.3 for details.

The parameter files stored in this directory are:

```
ro  DazMain.txt     contains factory parameters
rw  DazCurrent.txt  settings optionally saved upon exit
rw  wave.txt        current waveform parameters
```

Files marked `ro` (read only) are factory settings and should NOT be changed without consultation with Fastlite. The other files are read and written by the application program to optionally save conditions from execution to execution. All files may be commented by text starting with the exclamation mark "!". However, files which are `rw` (read/write) cannot unfortunately keep user-added comments, as they are overwritten by the software, but each parameter contained in these files should already be described by a short comment.

B.2.2 DazMain.txt

This is the major file defining the Dazzler system. This file contains different sections of type [*section_name*], in which are stored the different factory parameters needed to describe the generator. For example, the software uses this file to determine if the generator has the $T2$, or $Tunable$ options implemented.

This file has been created by Fastlite and should never be changed. Otherwise, the generator and software might completely stop working.

B.2.3 DazCurrent.txt

This file contains the parameters optionally saved upon exit by the software to be kept for the next execution. Hence this file is only written if the user answers "yes" when asked "Do you want to save the current settings for next restart?".

This file also contains different sections, the main one being [$Trig\&Mode$], which contains all the parameters of the "Trigger & Mode" panel.

Though being marked `rw`, this file should rarely have to be changed by hand. Parameters should be changed during the software execution, and saved upon exit.

B.2.4 wave.txt

This file keeps the main panel control values for re-use on the next start. Users wishing to operate the remote control options will use this file to find the names and syntax of the various knobs and controls.

When the stored waveform was using the files "`AMP.TXT`" or "`PHASE.TXT`", the contents of these two files are stored in "`wave.txt`". When the waveform parameters are restored, the contents of the files "`AMP.TXT`" or "`PHASE.TXT`" are overwritten back to what they were when the waveform was saved.

The same principle applies for the waveforms using "combination" between multiple buffers. Each of them is saved and restored when reading the wave file.

The trigger settings are also stored in the "`wave.txt`", but are only here as a reminder. Trigger settings are NOT modified when the waveform parameters are restored.

B.2.5 Other Files

Some other files may be found among other parameter files. These are generally calibration data files, that have been generated at the factory, and used to generate `DazMain.txt` and `DazCurrent.txt` files. Here is a very short description of the different files you may find in your parameters directory.

```
ro  filter.txt     small signal response of the RF generation
ro  tunfilter.txt  calibration data of adjustable filter (tunable option)
ro  displays.txt   possible output signals names
```

B.3 Changing Location of Parameters Files

You may have to indicate the location of your parameters by hand to the software, especially after a reinstallation on another computer. To do this, first delete the file "<Dazzler Software Directory>/params.txt", then start the software. The windows shown on Figure B.1 should appear.

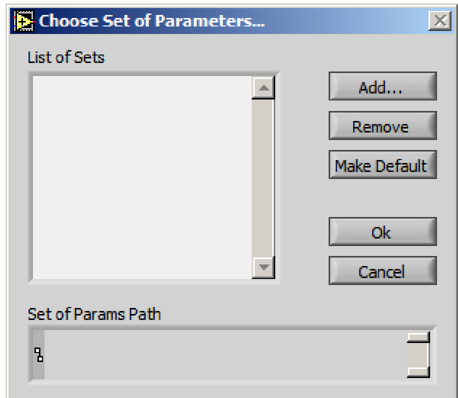


Figure B.1: Selection of Parameters Directory

Choose "Add...", and browse your filesystem to find the directory containing your parameter files. When you are **INSIDE** your parameter directory, choose "Select Current Dir...". The name of the selected directory should appear into the list of parameters sets, and when this name is highlighted, you should read its complete path below the list.

To allow the software to start automatically using your set of parameters, you should then click once on "Make Default". When the window looks like Figure B.2, just click "OK". The software should then start normally using the selected parameters.

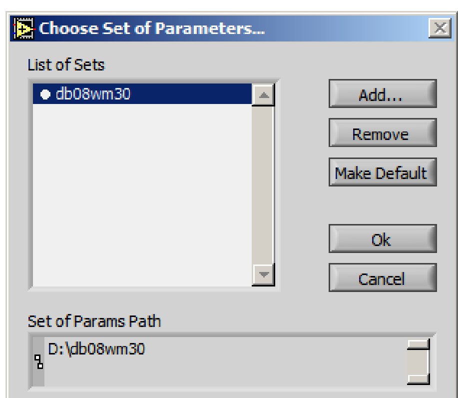


Figure B.2: Parameters Directory Selected

B.4 Troubleshooting

B.4.1 Missing parameters

Some parameters are absolutely required by the software to start. If they are not present, the software will not start. Some other are considered "optional" : they are generally written as such in parameters files comments. The absence of one of these last will not prevent the software to work.

If you encounter an error message telling that one required parameter is missing, please contact Fastlite for support on solving the issue.

B.4.2 E-mail reports

Please, in case of any problem, get in touch via e-mail with as much information as possible in "computer ready format" at the address: info@fastlite.com

B.4.3 Screen captures

To help us understanding your problem please send us as much screenshots as possible. Irfanview software can be used to perform screen captures. This software should have been installed by fastlite on your computer prior to shipment. If you cannot find it for any reason, please reinstall it : this is free software that you can find on the web.

The procedure is then the following : select Options, then Capture, use defaults. Switch back to the window to be captured (click into it to bring it to the forefront), and press control+F11. Save the captured file using the PNG format, most appropriate for screen dumps.

APPENDIX

C

DAZZLER ALIGNMENT AND CALIBRATION

The following note describes the procedure to align and calibrate the crystal for the case of a Dazzler operating at the output of a seed oscillator. The principles described here can be readily extended to other implementation cases, with some modifications in the measurement procedures . In case of difficulty, contact Fastlite.

C.1 Alignment

The diagram on Figure C.1 shows the geometry of the crystal. The z axis is perpendicular to the input face and is the direction of input optical beam. The x direction is perpendicular to z and in the plane of diffraction. The y direction is perpendicular to the plane of diffraction. The acoustic beam region is patterned with dots. The direction of the diffracted and direct (non diffracted) beam are shown. A diode detector will be placed either at position B (diffracted beam) or position A (direct).

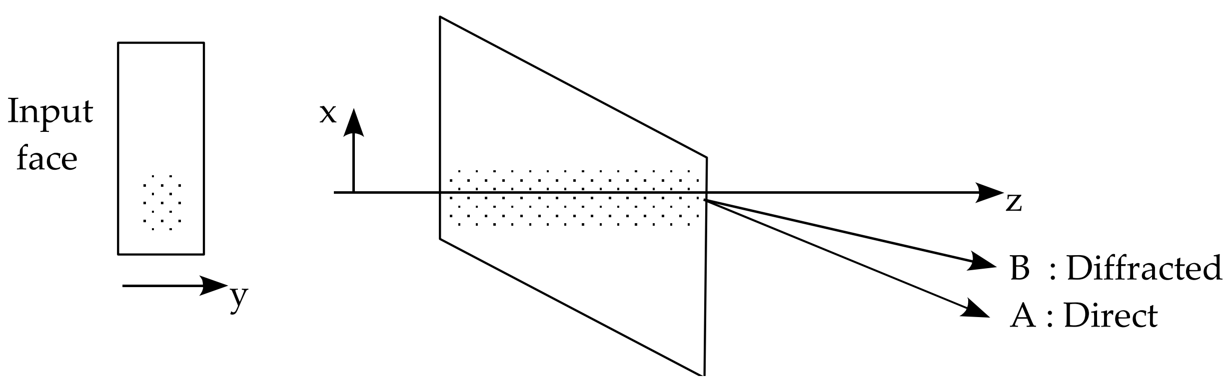


Figure C.1: Crystal Geometry

An oscilloscope is needed to measure the diode output. A view of the input face from the left is also shown.

The beam should be fully contained in the diode detector. If the detector area is too small, focus the beam achieve this condition. It is not necessary that the detector resolve the individual pulses for the oscillator. In fact a simple diode loaded with $1k\Omega$ resistor driving a high impedance scope through a 1 meter coaxial cable will yield a $0.1\mu s$ response time adequate for the measurement.

The crystal should be mounted so as to have rotational control to align the laser beam perpendicular to the input face with about $1mRad$ accuracy and translational control along the x and y directions ($0.1mm$ accuracy).

The trigger can be done with the internal generator, connecting the $S2$ output to the trigger input on the front panel. Set a $10kHz$ repetition rate. Use the trigger signal to to synchronize the oscilloscope. Set the Dazzler in single shot mode.

The procedure is the following:

1. Align the beam from the mode locked oscillator perpendicular to the input face (autocollimation from the input face). Polarization should be along y axis.

2. Program the Dazzler waveform with a bandwith covering the oscillator bandwidth and a second order phase coefficient so that the signal covers the full delay range in the time display panel. Use a 50% power setting.

3. Observe the diffracted beam and align the diode on this diffracted beam (B position).

4. Observe the diffracted signal on the scope. Move the x and y position of the crystal to assess the position of the acoustic beam (approximate dimensions $5 \times 8mm^2$). Set the x and y positions so that the laser beam is approximately in the center of the diffraction region.

5. Change the waveform of the Dazzler to produce a short acoustic signal by reducing the second order phase coefficient (see Figure C.2).A typical signal on the oscilloscope is shown for this example The duration of this signal is the propagation time through the crystal t_{xtal} typically $20\mu s$ (exact value is displayed inside the *"Trigger and Mode"* panel). Its shape reflects variations of the acoustic field in the crystal associated with the acoustic diffraction pattern. As you move the crystal, along the x direction, the scope trace will be shifted in time, due to the change of the acoustic propagation time from the transducer to the input face. When moving the crystal along the y direction, the onset of the signal remains constant in time but the shape changes. Adjust the y position to obtain an approximately flat pattern.

C.2 Frequency Calibration

Use an amplitude spectrum with a narrow hole (example on Figure C.3).

Feed the diffracted beam into a well calibrated spectrometer. Check the wavelength at which the hole feature appears. If a difference occurs with the programmed value , modify the parameter *"ratio"* by a factor corresponding to the relative wavelength change in the "`DazMain.txt`" file (see the note concerning parameter files). Restart the program and check that the calibration is now correct. Verify that the calibration remains valid for other wavelength positions of the hole feature.

Alternatively, for small calibration errors of order 1 nm, it is possible to adjust the crystal angle, i.e. deviate slightly from perpendicularity to the input face, by rotating around the y axis.

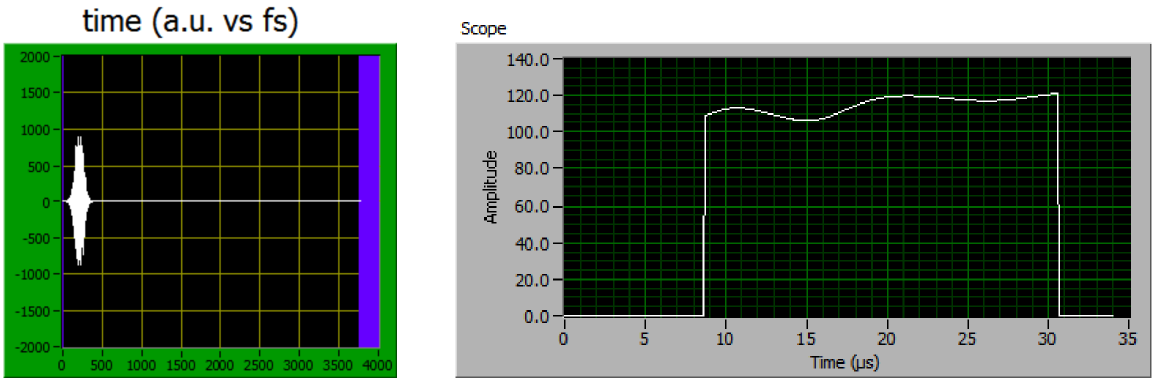


Figure C.2: Short Acoustic Pulse and Typical Oscilloscope Measure

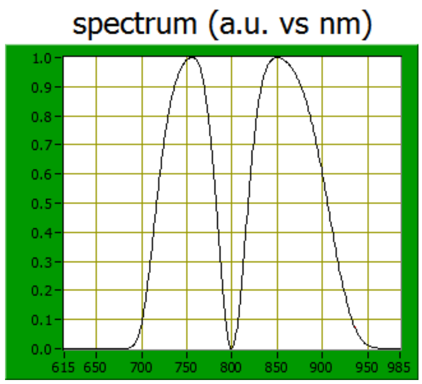


Figure C.3: Example of Spectrum With Hole

The ratio of optical to acoustic frequencies is sensitive to this angle allowing adjustment of the calibration.

C.3 Diffraction efficiency

Put the detection diode on the direct beam (A position). Use an amplitude spectrum with a width of 100nm. Extend the signal to cover the full range of delays, by adjusting the second order phase coefficient. Use the full power.

Observe the drop of signal on the scope. The maximum drop should be at least 50% for a laser source of bandwidth smaller than 100nm.