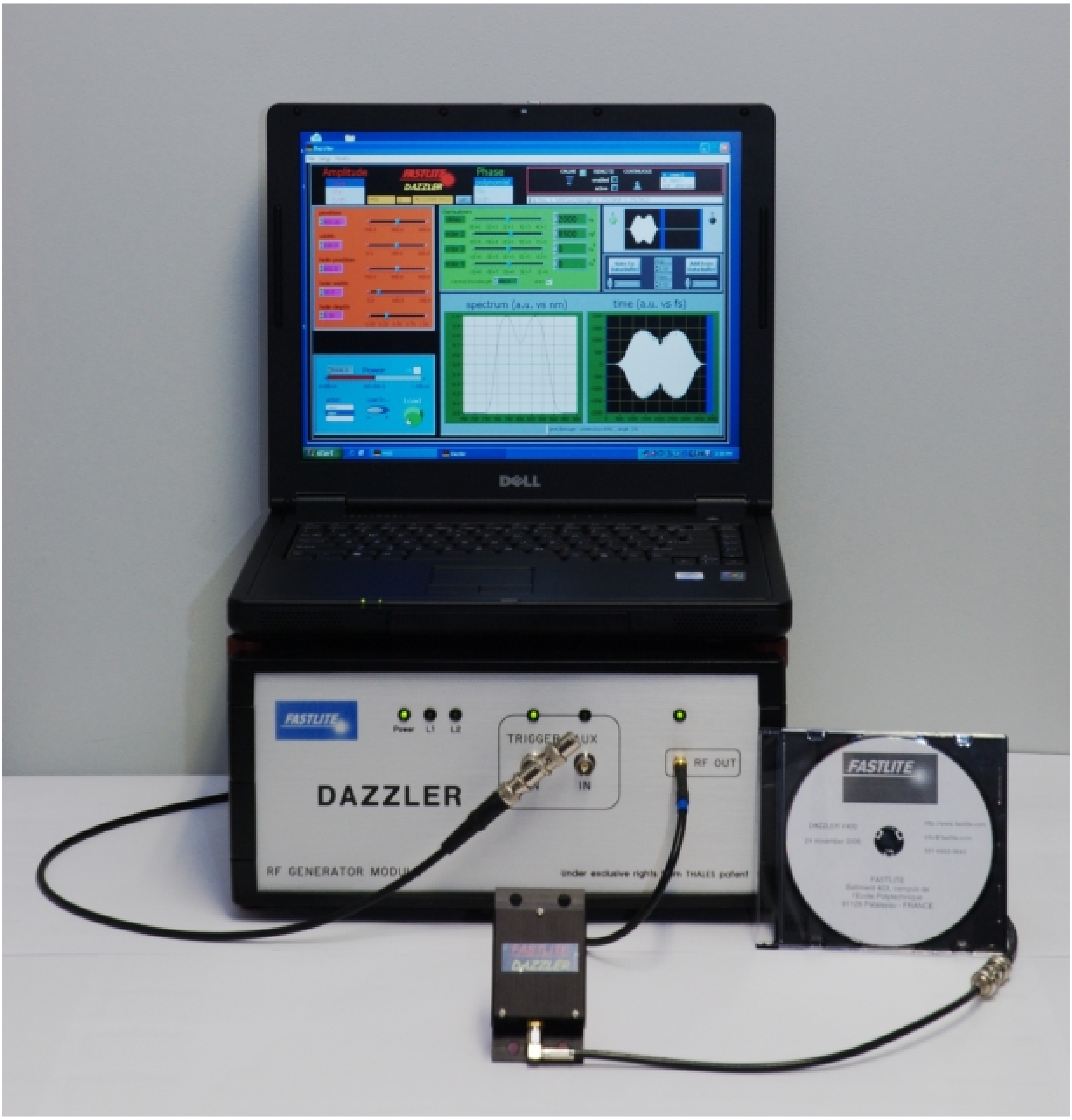
DAZZLER
FASTLITE
Power
L1
L2
TRIGGER
AUX
IN
RF OUT
DELL

Contents

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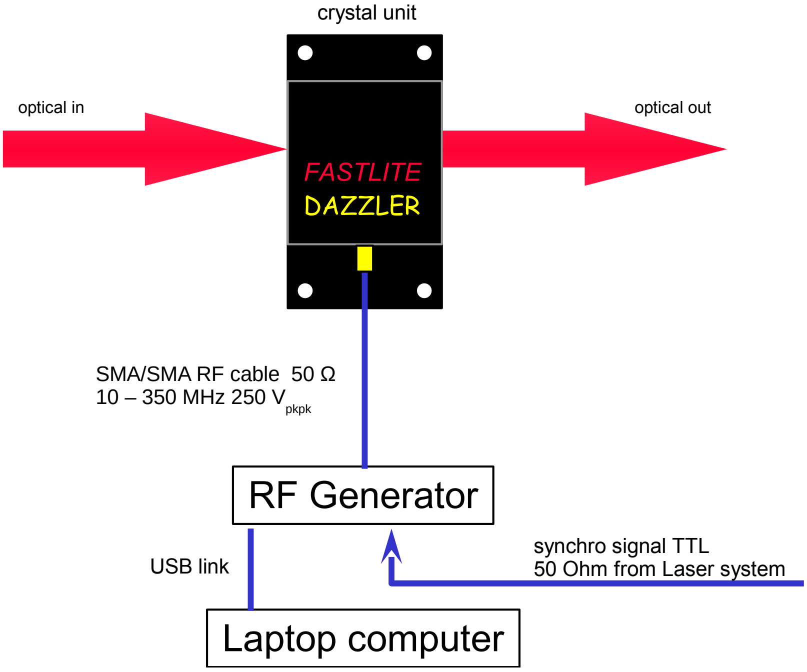
CHAPTER 1

Introduction

1.1 System components

The DAZZLER system is an acousto-optic programmable dispersive filter. It enables to control separately both spectral amplitude and spectral phase. The DAZZLER system is composed of three main parts:



- an acousto-optic crystal
- an RF generator
- a Laptop computer

1.1.1 Crystal unit

The crystal is an active component which through the acousto-optic interaction allows to shape the spectral phase and amplitude of an optical pulse.

The theory and performance of this interaction are described in chapter 2. This unit is intended to be inserted in the beam and will physically interact with it in order to pre or post compensate the phase and the amplitude distortions of the beam.

For proper operation, the acoustic and optical beams must be aligned and the acoustic wave has to be synchronized with the optical pulse: for details, see Figure 3.3 and chapter 4.

IMPORTANT *Note that the damage threshold of the crystal is 100Mwatt/cm^2 for ns pulses or 30μJ/pulse for sub-ps pulses with 2.5 mm input beam diameter. The crystal may be damaged if a high-power optical beam is injected. Also note that the crystal warranty is void if you remove its cover.*

1.1.2 RF generator

The RF generator is the electronic unit which translates the signal digital definition in the computer into the analog high power RF electrical signal driving the crystal. It also provides essential ancillary signals for interfacing with the laser system, such as the synchronization of the optical and acoustic waveforms (triggering process) and other functions that cannot be handled by the computer.

The generator produces a sampled arbitrary waveform signal. The signal repeats periodically when the unit is programmed in the "continuous" mode and is generated only once for each trigger signal in the "single" mode.

On the front panel TRIGGER and AUX are inputs controlling the generation process.

The rear panel BNC outputs **S1, S2, S3** and **S4** are used for driving data acquisition & control equipment, control and as well as monitoring signal with an oscilloscope for troubleshooting. A detailed description of the front and rear panel signals can be found in subsection 8.7.3 while section 8.2 describes the six front panel LED indicators.

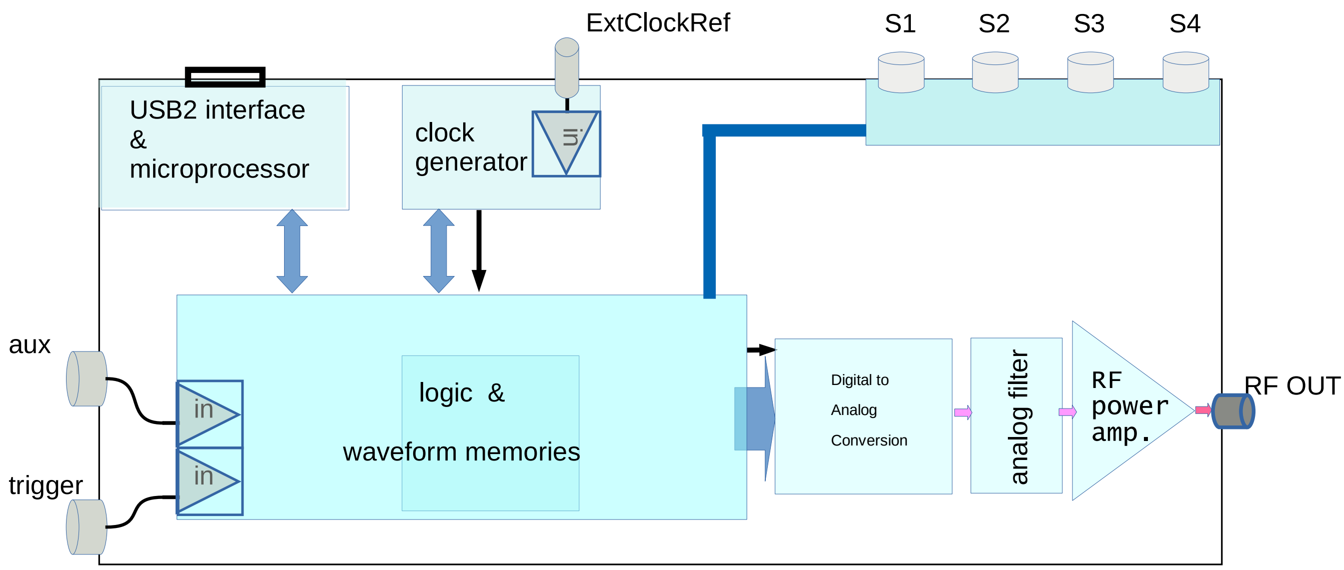


Figure 1.1: Simplified schematic of the RF generator

1.1.3 Laptop computer and software

A laptop computer is provided to drive the system, It performs the following functions:

1. communication initialization
2. zeroing of RF signal
3. spectrum generation from amplitude function $A(\omega)$ and phase function $\varphi(\omega)$
4. setting of central frequency (wavelength) for $A(\omega)$ and $\varphi(\omega)$
5. dial programming of $A(\omega)$ as supergaussian (power 6) of given width with gaussian hole
6. dial programming of $\varphi(\omega)$ as a polynomial
7. reading $A(\omega)$ and $\varphi(\omega)$ from files
8. setting of the waveform amplitude and duration
9. storing and retrieving of waveforms for waveform combination (multiple pulses)
10. sending (launching) waveform to the RF unit
11. choice of two waveforms or to alternate at each trigger between two stored waveforms

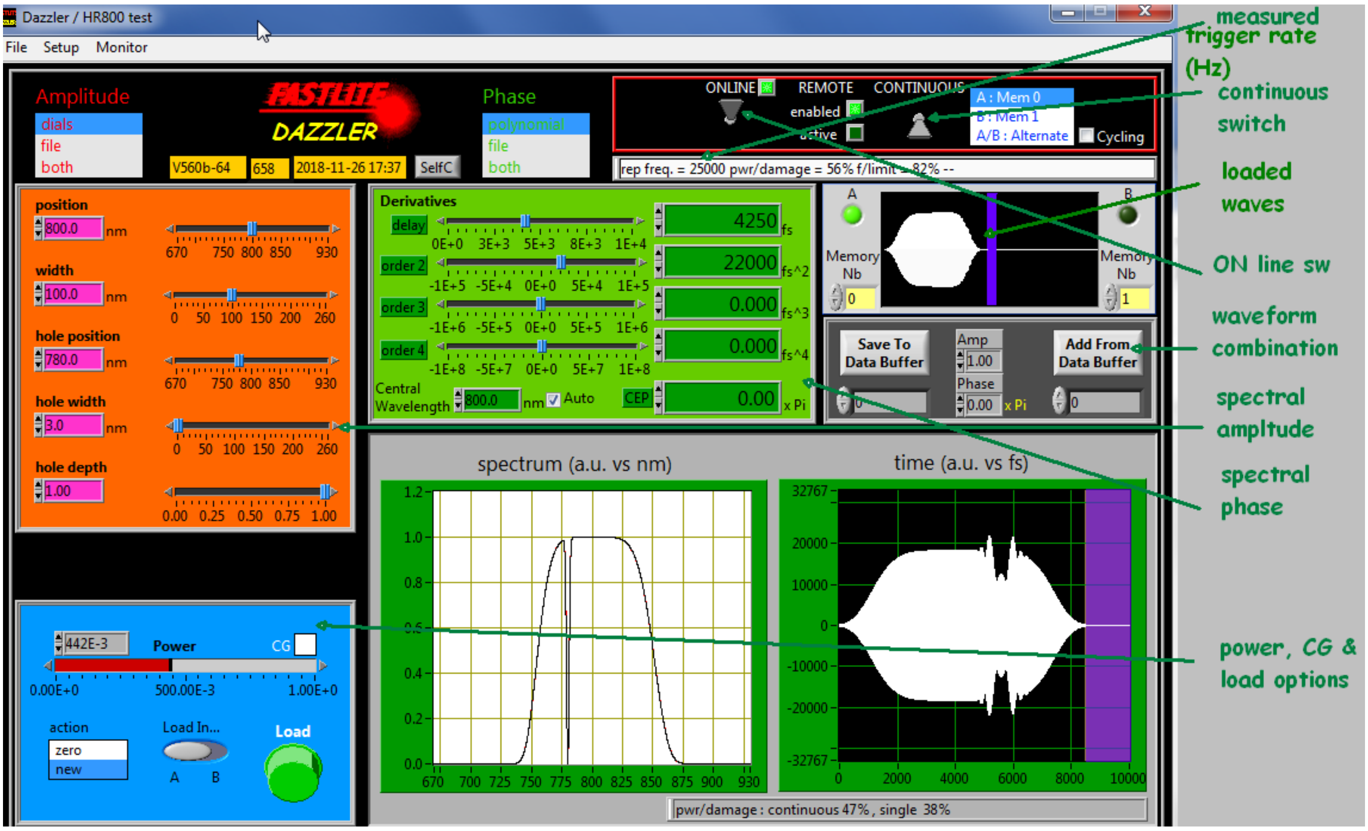


Figure 1.2: Dazzler^{TM} software front panel

All the above programmation is done from the main program GUI panel (Figure 1.2). The trigger settings require a separate panel. Other functions are available via menu commands:

1. saving and retrieving panel parameters in files
2. setting of the trigger conditions

3. enabling/disabling remote control mode
4. various monitoring functions

Details are found in chapter 5. The GUI main panel is shown with superimposed dark green arrows to the controls mentioned below:

CHAPTER 2

Physics

The Dazzler system is an Acousto-Optic Programmable Dispersive Filter (AOPDF). This chapter briefly describes the physical principles of the device. All the figures illustrate the standard AOPDFs configuration based on a Paratellurite crystal (TeO2).

2.1 AOPDF principle

In an AOPDF, the pulse shaping mechanism arises from a copropagative interaction between a polychromatic acoustic wave and a polychromatic optical wave in a birefringent crystal with acousto-optic properties. When the right physical conditions are met (the so-called phase-matching conditions), the input optical and acoustic beams interact and give rise to a new optical beam, which is referred to as the diffracted beam. Section 2.1.1 describes the phase-matching conditions whereas section 2.1.2 details one special feature of the acousto-optic interaction in an AOPDF: the collinearity in terms of Poynting vectors. Section 2.1.3 gives more details on the pulse-shaping mechanism.

2.1.1 Phase-matching conditions

As for all three-wave mixing processes, the phase-matching condition for monochromatic plane waves is defined by two conditions:

- wave-vector conservation (momentum conservation)
- frequency conservation (quantum energy conservation)

Mathematically, these conditions can be expressed as:

$$\begin{cases} \vec{k}_{\text{diff}}\left(\omega_{\text{opt,diff}}\right) = \vec{k}_{\text{in}}\left(\omega_{\text{opt,in}}\right) + \vec{k}_{\text{ac}}\left(\omega_{\text{ac}}\right) \\ \omega_{\text{opt,diff}} = \omega_{\text{opt,in}} + \omega_{\text{ac}} \end{cases} \tag{2.1}$$

where $(\vec{k}_{\text{diff}}, \omega_{\text{opt,diff}})$, $(\vec{k}_{\text{in}}, \omega_{\text{opt,in}})$ and $(\vec{k}_{\text{ac}}, \omega_{\text{ac}})$ stand for the wave-vectors and angular frequencies of the optical diffracted beam, optical input beam and acoustic beam respectively.
For the standard AOPDFs, based on TeO_2, the input optical beam is usually *ordinary* polarized, the diffracted beam is *extraordinary polarized* and the acoustic beam is a shear wave.
Since the velocity of sound in crystals is much lower than the velocity of light, the acoustic frequency is completely negligible with respect to that of light ($\omega_{\text{ac}} \ll \omega_{\text{opt}}$) so that the phase-matching condition reads finally:

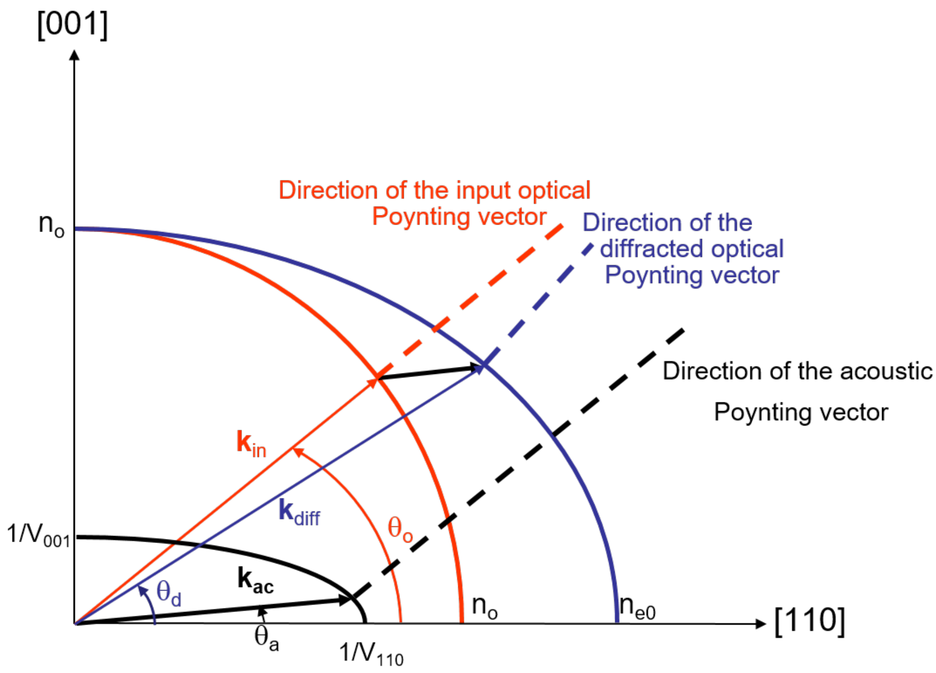


Figure 2.1: Phase-matching conditions and Poynting vector directions

$$\vec{k}_{\text{diff,e}}\left(\omega_{\text{opt}}\right) = \vec{k}_{\text{in,o}}\left(\omega_{\text{opt}}\right) + \vec{k}_{\text{ac}}\left(\omega_{\text{ac}}\right) \tag{2.2}$$

Figure 2.1 shows the ordinary and extraordinary (optical) index curves for the birefringent cystal as well as the acoustic slowness (inverse velocity) curve in the plane defined by the [001] and [110] axes. The incident optical and acoustic wave vectors make respectively an angle θ_o and θ_a with respect to the [110] axes. The acousto-optic interaction is not collinear in terms of wave vectors. The diffracted wave propagates along the extraordinary axis with an angle θ_d (with respect to the [110] axis) given by the phase-matching conditions (Equation 2.2).
For given propagation directions of the optical and acoustic beams (θ_o and θ_a), the phase-matching relationship can be viewed as an implicit equation which links acoustic and optical frequencies. In thick crystals, this link is an almost one-to-one relationship (i.e. bijective) between acoustic and optical frequencies. In other words, a single acoustic frequency diffracts a single optical frequency.

2.1.2 Poynting vectors

In most acousto-optic modulators, a transverse acoustic wave interacts with the input optical wave. The input optical Poynting vector is perpendicular to the acoustic one under the phase-matching conditions. In the case of the AOPDF, the input optical and acoustic Poynting vectors are collinear (Figure 2.1). The interaction is longitudinal (energy consideration) which enables to maximize the interaction length between the two waves to obtain high spectral resolution (section 2.2.2) and diffraction efficiency (section subsection 2.2.1). This also entails the quasi-bijective relationship between acoustic and optical frequencies.

$$\omega_{\text{ac}}/\omega_{\text{opt}} = \nu_{\text{ac}}/\nu_{\text{opt}} = \alpha(\omega) \tag{2.3}$$

where α depends on the crystal properties (crystal birefringence) and the phase-matching geometry and is weakly dependent on ω. Fastlite has three standard geometries for TeO2 crystals, named WB, WR and HR. In the presentation most examples will be given using the HR geometry. For example, if $\lambda = 800$nm, the optical frequency is $\nu_{\text{opt}} = 375$THz and the matched acoustical frequency is: $\nu_{\text{ac}} = 85.93$MHz, $\alpha = 2.3\ 10^{-7}$. The small value of α enables to control optical signals in the hundred of Terahertz range with electrical signals in the tens of megahertz range.

2.1.3 Pulse-shaping mechanism

Two different approaches can be used to understand the pulse-shaping mechanism involved in AOPDFs: group delay control and time convolution. The first interpretation isn't rigorous but provides a direct and clear insight of this mechanism. The only rigorous approach is the time convolution one, which is practical for computations but less self explanatory.

Explanation in terms of group delay

A schematic of the AOPDF is shown in Figure 3.4 An acoustic wave is launched by a transducer excited by a time-dependent radio-frequency (RF) electronic signal. The acoustic wave propagates with a velocity V along the z axis and hence reproduces spatially the temporal shape of the RF signal.

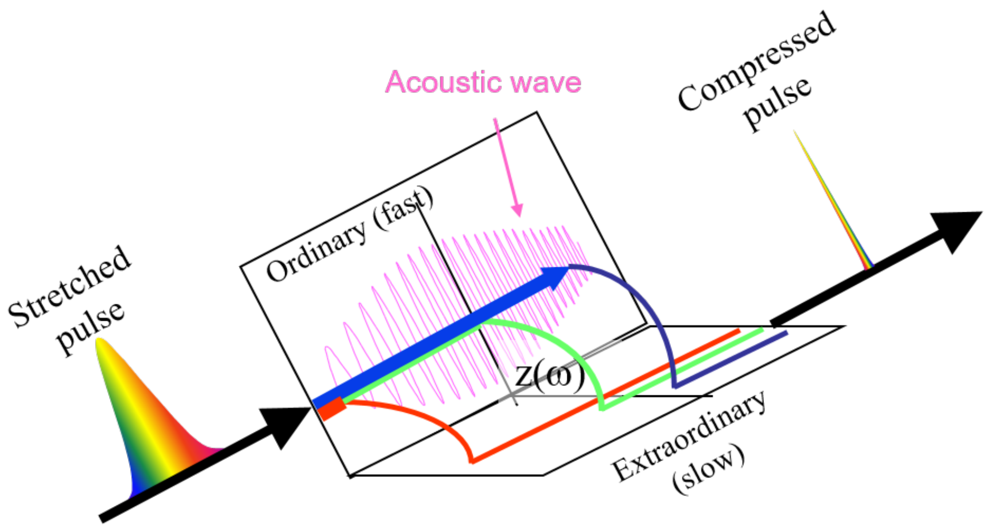


Figure 2.2: Explanation of the Dazzler principle in terms of group delay control

Let's take the case of a linearly chirped acoustic wave (Figure 2.2). If there is only one spatial frequency in the acoustic grating at position z, then only one optical frequency can be diffracted at position z. The incident optical short pulse is initially ordinary polarized. Every optical frequency ω travels a certain distance before it encounters a phase-matched spatial frequency in the acoustic grating. At this position $z(\omega)$, part of the energy is diffracted and gives rise to an extraordinary polarized component. At the crystal output, the diffracted pulse will be made of all the spectral components that have been diffracted at various positions. Since ordinary

and extraordinary polarizations travel with different group velocity, each frequency will see a different group delay.
The group delay τ applied to the diffracted pulse can be expressed by [1]:

$$\tau(\omega) = n_{g_o}(\omega)/c * z(\omega) + n_{g_e}(\omega)/c * (L - z(\omega)) \tag{2.4}$$

where n_{g_o} and n_{g_e} are respectively the ordinary and extraordinary group indexes along the propagation direction and L the crystal length.
Controlling for each optical frequency ω the position $z(\omega)$ where ω is diffracted enables to control the pulse group delay. The amplitude of the output pulse is controlled by the acoustic power at position $z(\omega)$.

Explanation in terms of time convolution

For low diffraction efficiency ($\ll$ 100%), the optical output complex electric field $E_{\text{diff}}(t)$ is proportional to the convolution of the optical input complex electric field $E_{\text{in}}(t)$ with the electric signal $S(t/\alpha)$ where α is the ratio between optical and acoustic frequencies (Eq. Equation 2.3)[1].

$$E_{diff}(t) = E_{in}(t) \otimes S(t/\alpha) \tag{2.5}$$

In the frequency domain, this convolution relation can be written:

$$E_{diff}(\omega) = E_{in}(\omega) \cdot S(\alpha\omega) = E_{in}(\omega) \cdot S(\omega_{\text{ac}}) \tag{2.6}$$

The spectral phase of the diffracted optical pulse $\varphi_{\text{diff}}(\omega)$ can be written:

$$\varphi_{\text{diff}}(\omega) = \varphi_{\text{ac}}(\omega_{\text{ac}}) + \varphi_{\text{in}}(\omega) \tag{2.7}$$

where φ_{ac} and φ_{in} are respectively the spectral phase of the acoustic and optical input waves. This relationship shows that the spectral shaping is performed via a phase transfer from the acoustic wave to the optical input one.

Let's consider $H(\omega)$, the AOPDF optical transfer function defined by:

$$E_{diff}(\omega) = H(\omega)E_{in}(\omega) \tag{2.8}$$

and:

$$H(\omega) = \sqrt{\eta(\omega)}\exp[\mathrm{i}\phi(\omega)] \tag{2.9}$$

where $\eta(\omega)$ is the AOPDF diffraction efficiency (subsection 2.2.1) and $\phi(\omega)$ the spectral phase programmed in the software and applied to the input optical pulse.
The spectral phase of the diffracted optical pulse $\varphi_{\text{diff}}(\omega)$ can be written:

$$\varphi_{\text{diff}}(\omega) = \phi(\omega) + \varphi_{\text{in}}(\omega) \tag{2.10}$$

In the time domain, the optical complex electric fields $E_{\text{in}}(t)$ and $E_{\text{diff}}(t)$ can be linked by:

$$E_{diff}(t) = E_{in}(t) \otimes h(t) \tag{2.11}$$

where h is the Fourier-Transform of AOPDF optical transfer function H. It is the AOPDF optical impulse time response.
Note: Due to the finite length of the crystal, the function $h(t)$ is inherently clipped. For this reason, the actual diffraction spectrum may differ from a programmed spectrum. This is visualized by the black (programmed) and red (actual) curves in the spectrum window.

2.2 Key parameters

In this section, the reader will find the most important parameters describing the acousto-optic interaction.

2.2.1 Diffraction efficiency

The general formula giving the output optical intensity[1] $I_{out}(\omega)$ in the plane wave and monochromatic approximation is [4]:

$$I_{out}(\omega) = I_{in}(\omega)\eta(\omega) \tag{2.12}$$

with:

$$\eta(\omega) = \frac{\pi^2}{4}\frac{P}{P_0}\text{sinc}^2\left[\sqrt{\frac{\pi^2}{4}\frac{P}{P_0} + \left(\frac{\Delta k\, L}{2}\right)^2}\right] \tag{2.13}$$

where:

- $I_{in}(\omega)$ is the input optical intensity,
- P the actual acoustical power density,
- $\Delta k = \left(\vec{k}_{\text{diff,e}} - \vec{k}_{\text{in,o}} - \vec{k}_{\text{ac}}\right).\vec{u}_{\text{ac}}$ is the phase matching mismatch along the acoustic propagation direction,
- L is the crystal length along the acoustic propagation direction,
- P_0 is a characteristic acoustic power given for the Dazzler^{TM}HR models:

$$P_0 = 3.7 \cdot 10^6 \cdot \left(\frac{\lambda}{L}\right)^2 \qquad \text{in W/mm}^2 \tag{2.14}$$

  - For $L = 25$ mm, $\lambda = 800$ nm, $P_0 = 3.8$ mW/mm^2
  - For $L = 45$ mm, $\lambda = 1\ \mu$m, $P_0 = 1.8$ mW/mm^2

When $P = P_0$ and $\Delta k = 0$, the transfer coefficient to the diffracted wave is 100%:

$$I_{out}(\omega) = I_{in}(\omega)$$

.

For sufficiently low values of P compared to P_0, the AOPDF response is linear with P and:

$$I_{out}(\omega) = I_{in}(\omega)\frac{\pi^2}{4}\frac{P}{P_0}\text{sinc}^2\left(\frac{\Delta k\, L}{2}\right) \tag{2.15}$$

[1] Unit is W/cm^2.

2.2.2 Spectral resolution

We now assume a perfect phase-matching for a set of frequencies and directions. If the input optical frequency is varied while all the other parameters are kept constant (directions, polarizations, acoustic frequency) then $\Delta k\, L \neq 0$ and the diffraction efficiency drops (sinc^2 function).
For $P < P0$

$$\delta\lambda_{1/2} = \frac{0.8 \cdot \lambda^2}{\delta n \cdot L} \approx 8.9 \cdot \frac{\lambda^2}{L} \tag{2.16}$$

δn being the index difference between ordinary and extraordinary waves on the propagation axis in the crystal. For HR Dazzler^{TM}systems,

- For $L = 25$ mm, $\lambda = 800$ nm, $\delta\lambda_{1/2} = 0.23$ nm
- For $L = 45$ mm, $\lambda = 1\ \mu$m, $\delta\lambda_{1/2} = 0.20$ nm

2.2.3 Number of independent programming points

If $\Delta\lambda$ is the bandwidth of input optical signal in wavelengths, the number of independent programming points of the AOPDF is:

$$N = \frac{\Delta\lambda}{\delta\lambda_{1/2}} = 1.25 \cdot \delta n \cdot L \cdot \frac{\Delta\lambda}{\lambda^2} \approx \frac{L}{8.9} \cdot \frac{\Delta\lambda}{\lambda^2} \tag{2.17}$$

- For $L = 25$ mm, $\Delta\lambda = 100$ nm@800 nm, $N = 439$
- For $L = 25$ mm, $\Delta\lambda = 300$ nm@800 nm, $N = 1318$
- For $L = 45$ mm, $\Delta\lambda = 20$ nm@1 μm, $N = 101$

2.2.4 Input beam angular aperture (divergence)

With a WB crystal cut, the divergence of the input beam must be inferior to:

$$\delta\theta_{1/2} = n_0 \cdot (\delta\theta_0)_{1/2} = 2.47 \cdot (\frac{\delta\lambda}{\lambda})_{1/2} = 22 \cdot \frac{\lambda}{L} \tag{2.18}$$

- For $L = 25$ mm, $\lambda = 800$ nm, $\delta\theta_{1/2} = 0.04°$
- For $L = 45$ mm, $\lambda = 1\ \mu$m, $\delta\theta_{1/2} = 0.028°$

The input beam divergence degrades the resolution.

2.2.5 Acoustic power density to drive n points

The acoustic power density needed to drive the N independent spectral points of subsection 2.2.3 for a total diffraction of these points is:

$$P_N = N \cdot P_0 = 4.15 \cdot 10^5 \cdot \frac{\Delta\lambda}{L} \qquad \text{in W/mm}^2 \tag{2.19}$$

- For $L = 25$ mm and $\Delta\lambda = 100$ nm, $P_N = 1.66$ W/mm^2
- For $L = 45$ mm and $\Delta\lambda = 20$ nm, $P_N = 0.18$ W/mm^2

2.2.6 Convolution with an acoustical linear chirp

If $\Delta\nu$ is the frequency bandwidth of the linear chirp, the acoustic power density needed to transfer totally the optical signal input to the optical signal output in a crystal of length L is given by:

$$P_N = 4.15 \cdot 10^5 \cdot \frac{\lambda}{L} \cdot \frac{\Delta\nu}{\nu} \qquad \text{in W/mm}^2 \tag{2.20}$$

If β is the slope ($\Delta\nu/T$) of the linear chirp, T being the acoustic time duration of the chirp, P_N can be written as:

$$P_N = 3.7 \cdot 10^4 \cdot \frac{\beta}{\nu^2} \qquad \text{in W/mm}^2 \tag{2.21}$$

For $\lambda = 800$ nm, $L = 25$ mm, $\nu = 85.93$ MHz, $\beta = 0.1$ MHz/μs, $P = 0.5$ W/mm^2.

2.2.7 Maximal pulse shaping capability

The maximal pulse shaping capability corresponds to the maximal group delay variation that can be introduced. Using Equation 2.4, the maximal pulse shaping capability $\Delta\tau_{max}$ can be expressed by:

$$\Delta\tau_{max} = \frac{[n_{ge}(\omega) - n_{go}(\omega)]\omega L}{c} \tag{2.22}$$

This relation can be written to first order in $\Delta n/no$[2]:

$$\Delta\tau_{max} = \frac{\Delta n_g(\omega)\cos^2\theta_o \omega L}{c} \tag{2.23}$$

where Δn_g[3] is the group birefringence of the crystal.

For HR25 Dazzler™systems, the maximal pulse shaping capability is 8.5 ps at 800 nm.

2.2.8 Crystal dispersion compensation

The Dazzler™crystal introduces an optical dispersion on the incident pulse corresponding to the propagation along the ordinary axis of a crystal with length L. The introduced group delay $\tau_{crystal}$ is:

$$\tau_{crystal}(\omega) = \frac{n_{go}(\omega)\omega L}{c} \tag{2.24}$$

This dispersion can be compensated by programming an acoustic wave inducing an inverse group delay variation in the diffracted beam (*SelfC* button in the Dazzler™software, section 5.1.3).

[2] Δn is the crystal birefringence, not the ordinary index.

[3] $\Delta n_g = n_{ge0} - n_{go}$

Limitations to the compensation of the crystal dispersion

The maximum group delay variation that can be introduced is limited by the maximal pulse shaping capability τ_{max} of the system (section 2.2.7). For large spectral optical bandwidths, the group delay variation that enables to compensate for the crystal dispersion exceeds the maximal pulse shaping capability.

2.2.9 Beam orientations

As shown on Figure 2.3, the diffracted beam makes an angle with the input direction. Actually in Fastlite crystals the transmitted beam is also deviated from the input beam because the output face is set at an angle with the input face. The refraction on the output face is designed to compensate small changes of the diffraction angle with wavelength. Please note that this implies that the input and output faces are not interchangeable The table below gives the angles of the diffracted and transmitted beams with regards to the input direction for the HR and WB Dazzler models.

	WB model	HRmodel
Diffracted beam angle (°)	1.0	1.4
Transmitted beam angle (°)	3.6	4.5

Another point to note is that there is inherently a displacement (no angular change) of the diffracted beam depending on the point of diffraction in the acoustic column. This phenomenon is called *walk-off* and it implies that the spectrum and/or delay depends slightly on position in the beam. This weak effect can be eliminated if needed by using a double pass geometry (application note "double pass").

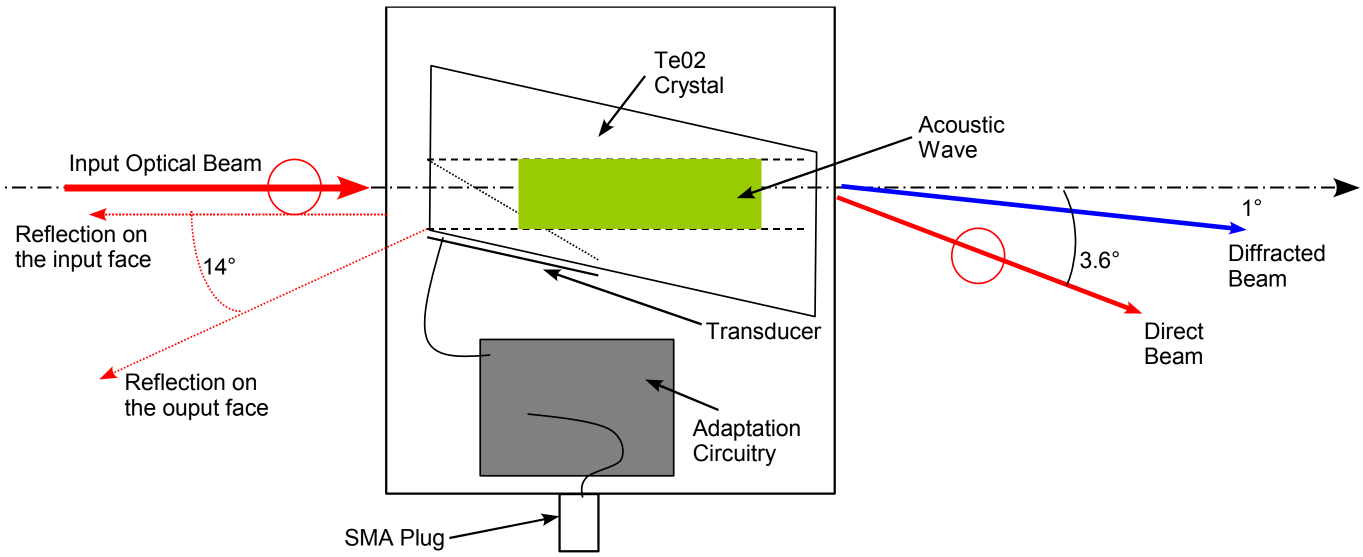


Figure 2.3: Diffracted and transmitted beams orientation for Dazzler^{TM}HR model

2.3 Formulæ

See a collection of useful formulæ overleaf.

Amplitude	Phase
$A_{dial}(\omega) = f(\omega).g(\omega)$	$\phi_{dial}(\omega) = h(\omega)$
$f(\omega) = \exp -((\omega-\omega_0)/\delta\omega_0)^6$	$h(\omega) = -(a_1\cdot(\omega-\omega_0) + \frac{a_2}{2}\cdot(\omega-\omega_0)^2 + \frac{a_3}{6}\cdot(\omega-\omega_0)^3 + \frac{a_4}{24}\cdot(\omega-\omega_0)^4)$
$\omega_0 = 2\pi C/\lambda_0$; $\lambda_0 =$ **position**	$a_1 =$ **delay** ; $a_2 =$ **second order**
$\chi_0 = \delta\lambda_0/(2\lambda_0)$; $\delta\lambda_0 =$ **width**	$a_3 =$ **third order** ; $a_4 =$ **fourth order**
$\delta\omega_0 = \omega_0\cdot(\chi_0-\chi_0^3)$	
$g(\omega) = 1 - k\cdot\exp -((\omega-\omega_1)/\delta\omega_1)^2$	
$\omega_1 = 2\pi C/\lambda_1$; $\lambda_1 =$ **hole position**	
$\chi_1 = \delta\lambda_1/(2\lambda_1)$; $\delta\lambda_1 =$ **hole width**	
$\delta\omega_1 = \omega_1\cdot(\chi_1-\chi_1^3)/2$; $k =$ **hole depth**	
Selector Control Setting	
dials $A(\omega) = A_{dial}(\omega)$	**polynomial** $\phi(\omega) = \phi_{dial}(\omega)$
file $A(\omega) = A_{file}(\omega)$	**file** $\phi(\omega) = \phi_{file}(\omega)$
both $A(\omega) = A_{dial}(\omega)\cdot A_{file}(\omega)$	**both** $\phi(\omega) = \phi_{dial}(\omega)+\phi_{file}(\omega)$
Spectrum combinations	
$S(\omega) = A(\omega)\cdot\exp(i\cdot\phi(\omega)) + \mathbf{a}\cdot\exp(i\cdot\phi)\cdot S_{saved}(\omega)$	

In the table above, $S(\omega)$ corresponds to the AOPDF optical transfer function ($H(\omega)$, section2.1.3).

CHAPTER 3

Installation & setup

This chapter describes the installation of a Dazzler: connections and settings for two typical experiments. Details will be found in the following chapters.

3.1 Connections

Before starting please verify:

- the input beam diameter (<2.5mm FWHM),
- the input beam polarization: linear, orthogonal to the diffraction plane (see Figure 3.3),
- the input beam energy/power: $< 30\mu$J/pulse for sub-ps pulses, < 100MW/cm^2 for ns pulses. For other pulse durations please contact Fastlite.
- the trigger signal: 0-4V TTL signal on 50Ω load. Minimum delay before the optical pulse depends on crystal (≃40-60μs).

The proper synchronization between the acoustic wave and the optical wave is obtained when the optical pulse goes through the crystal when the acoustic wave is filling the crystal. The Dazzler TRIGGER has to be fed a logic signal issued from the laser. The rising edge of this trigger signal occurs *Trigger to Laser* microseconds before the optic pulse going through the crystal. This time interval is approximately equal to the acoustic propagation time into the crystal[1]. The triggering configuration varies with the experimental setup (10Hz, kHz lasers, 100kHz). For operational details see chapter 4.

3.1.1 Connecting the unit and starting the software

1. connect the RF output to the crystal unit,
2. connect the USB A-B cable with ferrites to the host computer,
3. connect the grounding cable to the optical table (section 7.3),
4. install the crystal unit in the beam line. The crystal unit is not symmetric. The input face is the one close to the "D" of the "Dazzler" label. The output face is the one close to the "R" of the "Dazzler" label (Figure 3.3),
5. turn on the power switch on the rear panel of the RF generator. The waveform memory is zeroed at power on: there is no RF output.

[1]The acoustic propagation time depends on the crystal cut and its length. For 25mm long crystals, this time is 23.6 μs for WB cut, and 32.6 μs for HR cut. This time is called *TXtal* .

6. on the RF generator front panel, check that the green power LED indicator is lit (if not, there is no power, check AC mains), the L1 indicator blinks at 1Hz (not blinking indicates a communication failure or frozen microprocessor in the generator), and that the red LED indicator L2 is completely dark (L2 blinks when alarms are detected).
7. start the Dazzler software,
8. check that the software goes online: control switch on top (refer to Figure 1.2). It should be up. If not, flip it up (click above switch center) and notice error message if any,
9. connect the input trigger,
10. check that the trigger is correctly detected: trigger LED lit (generator unit), repetition rate is correctly measured and displayed,
11. check that the single mode is activated on the software front panel: CONTINUOUS switch down, to set it down, click below the switch center. (see subsection 5.1.7),
12. select the correct trigger settings (trig and mode panel of the Dazzler software, chapter chapter 4),

For cabling tips to limit the noise which may impair the proper operation of the system, refer to chapter 7.

3.1.2 Define the general settings

(Blue Area)

1. set the power level to 0.5,
2. check that the the CG box is unchecked (CG = constant gain),
3. select "new",
4. select "Load In...A",

3.1.3 Define the waveform combination options

(Grey area)

1. set the add waveform button to off.

3.1.4 Define the spectral amplitude

(Orange area)

1. check that dial option just below the "Amplitude" label is on "dials",
2. set the central wavelength (position) to a value appropriate to the laser source,
3. set the width to $\simeq$ 2.5 times the FWHM width of the laser source,
4. set the hole depth to 0.

3.1.5 Define the spectral phase

(Green area)

1. set the "delay" dial to a value corresponding to half of the crystal delay (for example, 4200fs for a 25mm HR-800 Dazzler), verify that the peak position on the "time" graph is roughly centered.
2. set the second order phase coefficient ("order 2") to a value producing a signal shape on "time" graph which is large enough to fill the full time window,
3. check that the spectrum graph does not show separate red and black curves. To keep black and red curves superposed, avoid clipping: reduce the time width of the signal ("order 2" control) and use the "delay" control to center in the time window.

3.1.6 Launching a waveform

1. press the LOAD (launch acoustic wave) button in the Blue Area,
2. set A memoryNb to 0 in the display mode selector in the Machine Control Area,
3. verify that the RF ON LED of the RF generator is lit,
4. and check that a waveform appears in the left hand side part of the "loaded waves" display (see subsection 5.1.6).

3.1.7 Stopping the Program

The program can be stopped by the menu file/exit item or by checking the red cross box at the top right corner of the window.
The user is asked to confirm the action, and whether the current status of the panels should be saved to be restored on the next program start up.
One should note that the RF generator is NOT STOPPED by exiting the program: to stop generating the acoustic signal, select the zero slider (Figure 5.2) and click on the LOAD button before powering off the RF generator.
WARNING: the parameters which are saved on exit DO NOT include the "action" selector[2]. If starting with a zero waveform is required, the power slider must be set to 0 before saving the parameters.

3.2 Examples of experimental setup

In this subsection, we show two different experimental setups. These setups give an overview of Dazzler applications in different kind of lasers. The first example is the implementation of a Dazzler in an ultrafast laser after the oscillator between the stretcher and the amplifier. The second example describes an experimental setup where the Dazzler is used after an Optical Parametric Amplifier.

[2] the memory "load in" selection A or B is saved, so is the display mode (A/B/AltAB). This may lead to believing the generator is not operating properly...

3.2.1 Ultrafast CPA laser controlled by a Dazzler

The Dazzler can be used to shape the spectral amplitude and/or the spectral phase of an optical pulse in an ultrafast CPA laser. The crystal unit is generally inserted between the stretcher and the amplifier (regen or multipass) because of its damage threshold (100MW/cm^2). Figure 3.1 below sketches this setup.

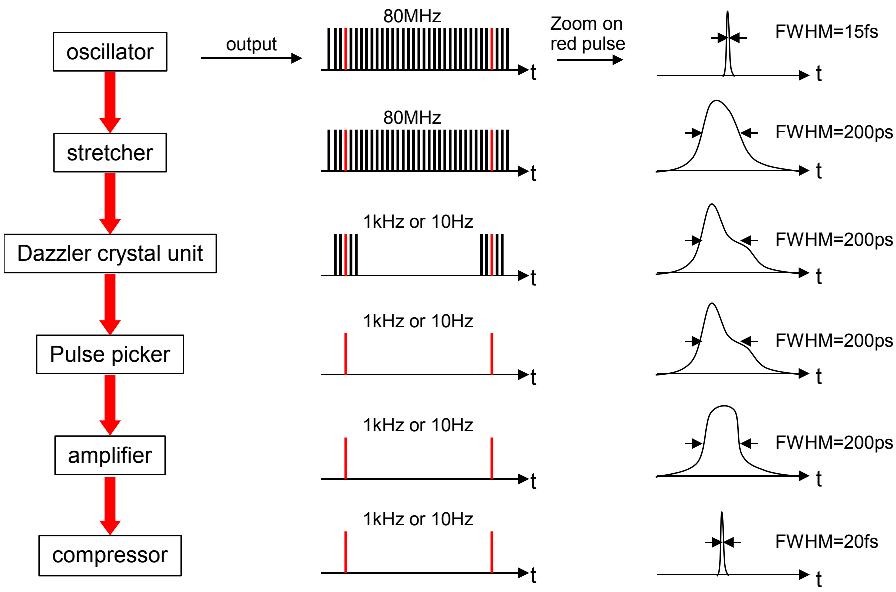


Figure 3.1: Setup of an Ultrafast CPA Laser with a Dazzler

The amplitude shaping enables to avoid gain narrowing and get a smooth spectral shape. In most of the cases, the spectral phase shaping is used to flatten the phase over the whole spectrum to obtain perfectly compressed pulses after the compressor. More complex pulse shaping can also be achieved such as multiple pulses or optimized pulse shape for a specific experiment.

3.2.2 Dazzler after an optical parametric amplifier

The Dazzler can be used as a pulse shaper at the output of an OPA. An example of setup is shown on the Figure 3.2.

The Dazzler enables to control the output pulse shape, for example the generation of two or more pulses separated in time. It is especially interesting in chemical or biochemical experiments where a molecule can be excited in a specific energy state which is unaccessible without pulse shaping. In the example of Figure 3.2, the Dazzler generates a sequence of shaped pulses at 750nm. Dazzler systems for other center wavelengths are available (contact us for further information at info@fastlite.com).

3.3 Optical Alignment

The input optical wave propagates through the crystal while interacting with the acoustic wave (refer to chapter 2 for more details). Two different waves leave the crystal: the diffracted and the transmitted (non-diffracted) waves as shown in Figure 3.3. The (P) plane corresponds to

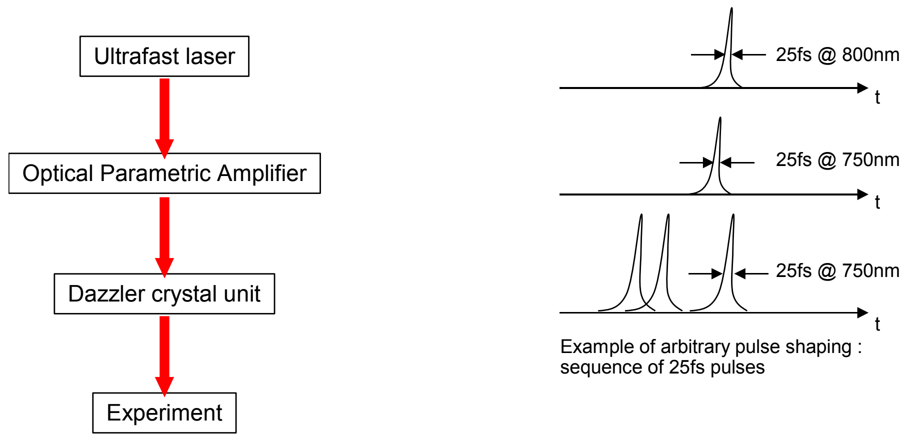


Figure 3.2: Setup of an OPA with a Dazzler

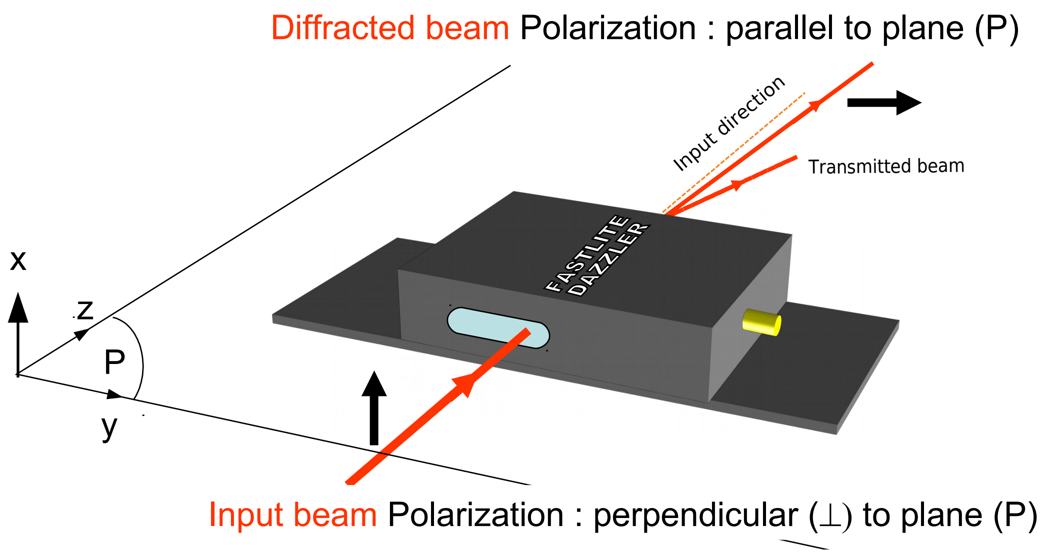


Figure 3.3: Dazzler crystal installation

the plane of diffraction. The z axis is perpendicular to the input face and is the direction of the input optical beam. The y direction is perpendicular to z and in the plane of diffraction. The x direction is perpendicular to the plane of diffraction. Note that while the input beam is polarized perpendicularly to the diffraction plane, the diffracted beam is polarized parallel to the diffraction plane. Make sure that the output polarization fits your laser setup.

For proper operation, the input optical beam has to be aligned with the acoustic axis (Figure 3.4). For a precise alignment, the crystal should be mounted so as to have rotational control to align the input beam perpendicular to the input face with about 1 mRad accuracy and translation controls along the x and y directions (0.1 mm accuracy).

First translate the Dazzler crystal to position the beam as described on Figure 3.5. Rotate the crystal to align the input beam perpendicular to the input face (autocollimation from the input face).

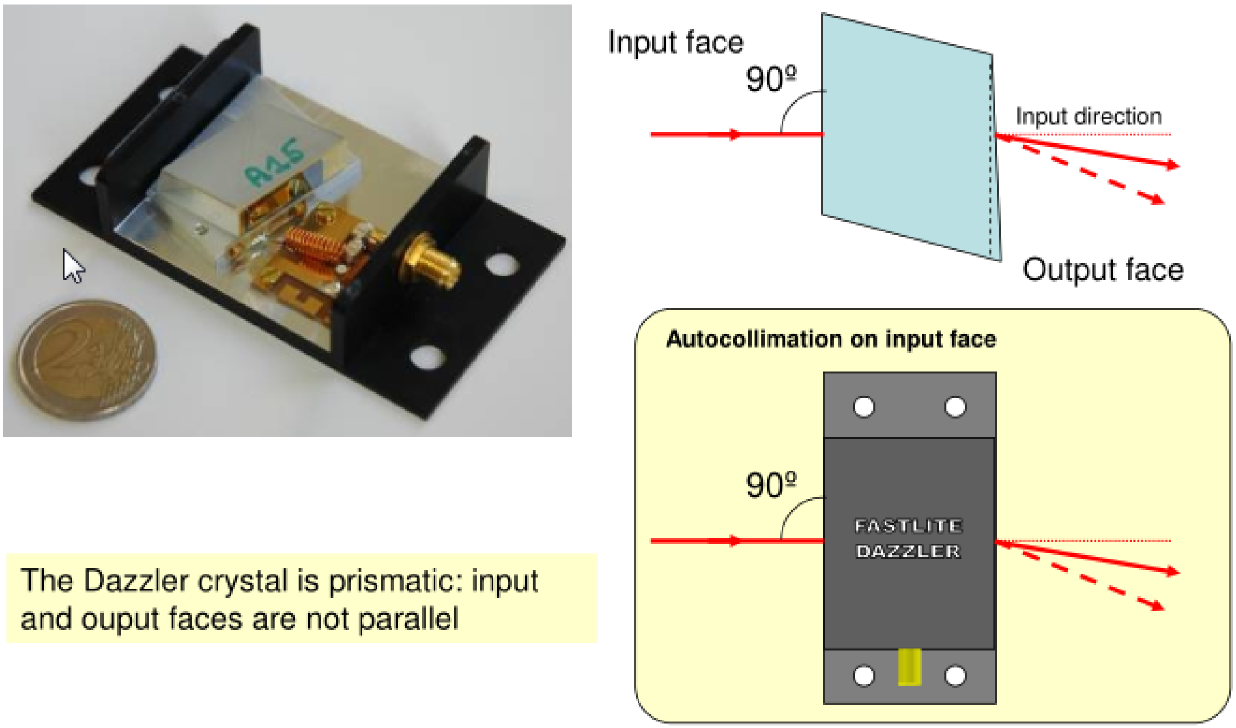


Figure 3.4: Details of the Dazzler crystal

3.3.1 Frequency Calibration

The Dazzler has qto be frequency calibrated to achieve accurate pulse shaping. Use an amplitude spectrum with a narrow hole (example on Figure 3.6).

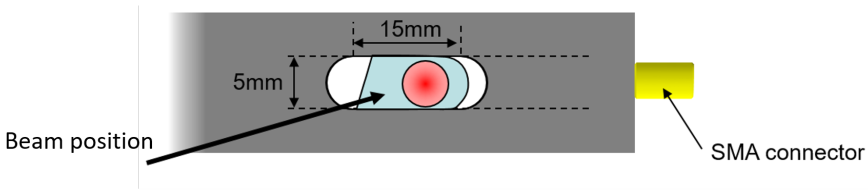


Figure 3.5: Beam position on the input face

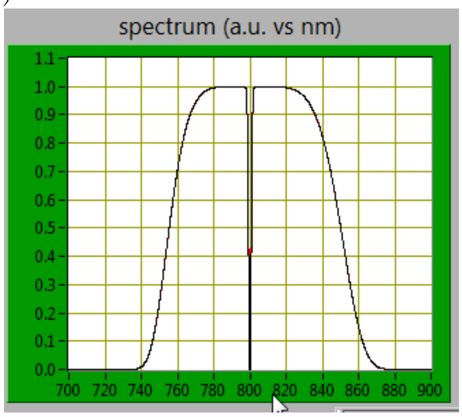


Figure 3.6: Example of spectrum with hole

Feed the diffracted beam into a well calibrated spectrometer. Verify the wavelength at which the hole feature appears. If a difference $d\lambda$ occurs with the programmed value and this difference is significant (i.e. larger than 10nm), there is a setup problem, a non exhaustive list of possible causes is:

- the input light polarisation orientation is incorrect
- the autocollimation is incorrect (e.g one degree error)

- the input face is not the correct face.
- the spectrometer is improperly calibrated
- the setup files are incorrect

If the difference $d\lambda$ is in the order of 1nm, then the calibration is best corrected by changing slightly the crystal orientation until the hole position matches the programmed hole wavelength. Verify that the calibration remains valid for other wavelength positions of the hole feature.
For the next steps of the alignment procedure, refer to subsection 3.3.2 if the Dazzler is operating at the output of a seed oscillator and to subsection 3.3.4 if not.

3.3.2 Dazzler operating at the output of a seed oscillator

A diode detector and a spectrometer will be placed on the diffracted beam. An oscilloscope is needed to measure the diode output.
The beam should be fully contained in the diode detector. If the detector area is too small, focus the beam to achieve this condition. It is not necessary that the detector resolve the individual pulses from 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 procedure follows:

1. observe the diffracted beam and align the diode on this diffracted beam.
2. 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.
3. change the waveform of the Dazzler to produce a short acoustic signal by reducing the second order phase coefficient (see Figure 3.7). 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 $20\mu s$ (the exact value is displayed in the *"Trigger and Mode"* panel, refer to section 4.2). Its shape reflects variations of the acoustic field in the crystal associated with the acoustic diffraction pattern. As you move the crystal, along the y 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 x direction, the onset of the signal remains constant in time but the shape changes. Adjust the x position to obtain an approximately flat pattern.
4. place a spectrometer on the diffracted beam and check that the whole input spectral bandwidth is measured.
5. check that the input beam is still autocollimated.
6. fine adjustment of the synchronization between the input optical wave and the acoustic wave using the trigger settings are described in chapter 4.

3.3.3 Measurement of the Dazzler diffraction efficiency:

The diffraction efficiency is defined by the ratio between the diffracted optical intensity and the input intensity (subsection 2.2.1). To determine this ratio we shall use the fact that the incident energy is equal to the sum of the transmitted and diffracted energies.

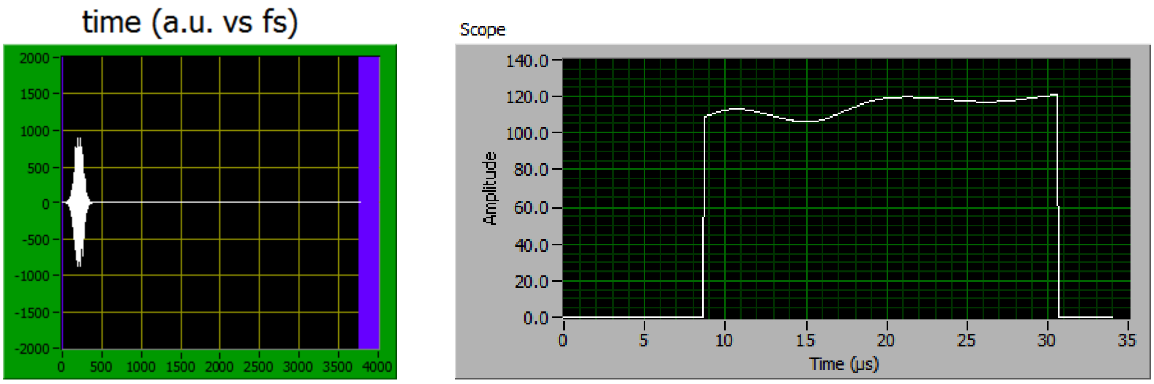


Figure 3.7: Short Acoustic Pulse and Typical Oscilloscope Measure

Put the detection diode on the transmitted beam (Figure 3.3). Change the second order phase value to cover 2/3 of the full time window on the software time graph and apply full power. Observe the drop of signal on the scope. The maximum drop corresponds to the diffraction efficiency of your Dazzler system. It should be at least 50% for a laser source of bandwidth smaller than $100nm$.
Your Dazzler system is now ready to be used. You can unblock the beam after the Dazzler and seed the amplifier with the diffracted beam.

3.3.4 Dazzler operating in other setups

The procedure follows:

1. measure the spectrum of the incident pulse with a spectrometer and save it as reference.
2. increase the second order phase coefficient ("order 2") on the GUI to produce a quasi-flat signal covering the full time window (Figure 3.8). Do not pay attention to the red curve on the spectrum graph. The signal is willfully truncated in the crystal to adjust the superposition of the optical incident pulse with the acoustic wave. Please keep in mind that for other Dazzler operations, the red and black curves have to be superimposed.
3. measure the diffracted spectrum.
4. adjust the x and y position of the crystal to closely match the reference spectrum shape.
5. check that the input beam is still autocollimated.
6. finely adjust the synchronization between the optical wave and the acoustic wave using the trigger settings as described in chapter chapter 4.
7. check as the spectral clipping displayed on the spectrum graph is the same than the one measured on the diffracted spectrum (Figure 3.8).

Your Dazzler system is now ready to be used.

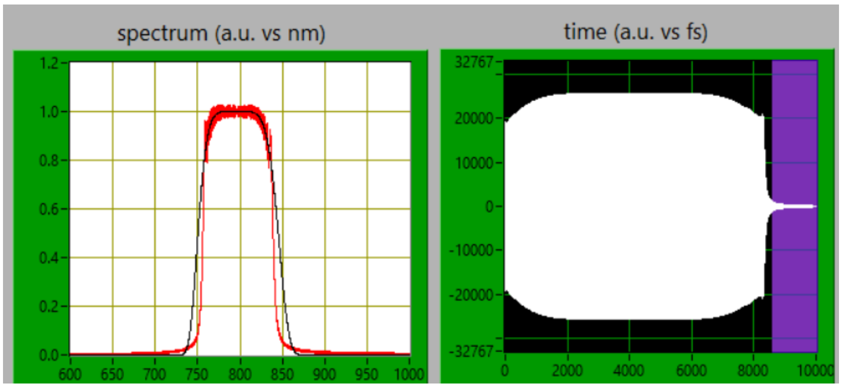


Figure 3.8: Chirped Pulse used to adjust the x and y position

CHAPTER 4

Triggering

4.1 Triggering issues in the Dazzler™

To work properly, the Dazzler™RF generator must be fed with an external synchronization signal coming from the user setup. This chapter details all (almost) you need to know about the trigger signal. It explains the type of wiring and signal to use, how to adjust the trigger timings for an accurate synchronization of the acoustic wave with the optical event and,the different software features available. Please refer to chapter 7 to reduce perturbations from EMI and noise.

There are applications which require that the trigger pulse be synchronous with the sampling clock. This can be achieved by locking the sampling clock and the trigger pulse to the laser pulse train. The "LowJitter" option has been designed for these cases. It is described in a specific document.

There was a major change in the user interface to set the trigger parameters introduced in V520[1]. The following description is valid for software versions V520b and above.

4.1.1 Wiring and signal level

The external synchronization signal connected to the TRIGGER BNC input of the RF generator must be properly terminated[2]: the pulse signal should come from a 50Ω source via 50Ω cables and be terminated properly with a 50Ω load. Make sure to follow the prescriptions given in Figure 7.2.

4.1.2 Optimum trigger settings

Due to the propagative nature of acoustic waves, one needs to adjust timings for the acoustic pulse to be exactly in the appropriate position when the light pulse goes through the crystal. This means that the acoustic wave must be generated long enough before the optical event. Determining the delay between the start of RF generation to the optical event involves the following parameters:

- **item-1** Time lost during propagation of electronic RF pulses inside the different parts of the generator and cables (less than a few 100 ns)[3].

[1] V520b was implemented September 2011.

[2] to avoid reflections which will create instabilities on the trigger time point.

[3] cable delay is around 5ns per meter

- **item-2** The acousto-optic transducer, being non-transparent, is not situated on the optical input face, but on a side of the Dazzler crystal (Figure 3.4). Hence the acoustic pulse needs time to propagate from the transducer to the optical input face.
- (item-3) After the reflection, the acoustic pulse still needs to travel between the optical input and output faces (a few tens of μs , depending on the crystal cut and length). This propagation time is displayed in the *TXtal* indicator.

The propagation times **item-1** and **item-2** are lumped in the T_p indicator. The delay between the start of the RF generation to the optical event is: $T_p + TXtal$. T_p and *TXtal* are parameters given to the Dazzler™software. Synchronization of the optical event(pulse) can be obtained based on:

- the propagation of light in the crystal is instantenous
- the duration of the acoustic wave is less or equal to *TXtal*
- there is enough 'early' warning time: *Trigger to Laser* $>= T_p + TXtal$
- starting RF generation in advance so that the acoustic (RF) wave is fully in the crystal, without clipping
- a less demanding condition is possible when starting the RF cycle by the delayed **previous** trigger pulse[4]. This mode of operation is called *Trig on Previous* mode, see subsection 4.3.2.

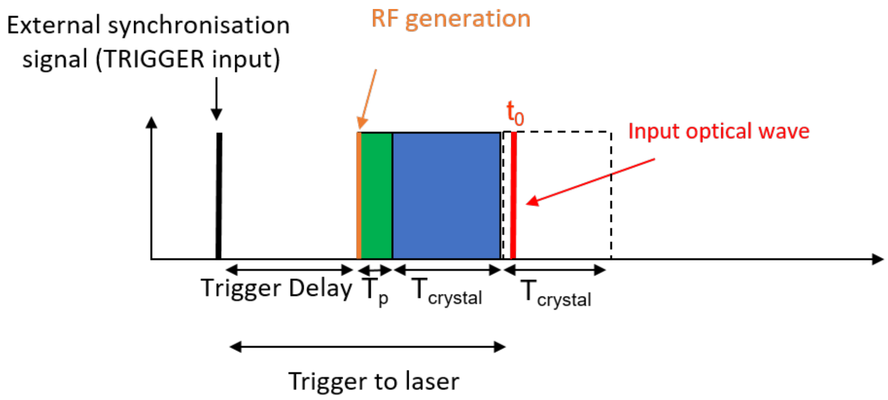


Figure 4.1: Optimum TRIGGER settings

Figure 4.1 shows when these conditions are fulfilled, resulting in a positive *Trigger Delay* . With these settings, the acoustic wave is fully contained in the crystal when the optical wave goes through.
To illustrate the effect of *Trigger Delay* , one uses the software time and spectrum graphs (see subsection 5.1.5). The *spectrum (a.u. vs nm)* graph represents the amplitude response of the filter ($|H(\omega)|$ defined in section 2.1.3). The black curve represents the programmed spectral amplitude, the red (oscillating) curve includes the time gating of the crystal. Due to the finite length of the crystal, the spectrum actually generated corresponds to the red curve. These two curves should be superimposed for proper operation. The *Time (a.u. vs fs)* graph shows the simulated optical impulse time response of the filter vs fs ($\mathtt{Re}(h(t))$ defined in section 2.1.3). This allows to verify if the signal is entirely in the time gate (delimited by the purple rectangle). If there is no clipping of the acoustic wave, the black and red curves are superposed.

[4]this is possible because the trigger is periodic with excellent stability

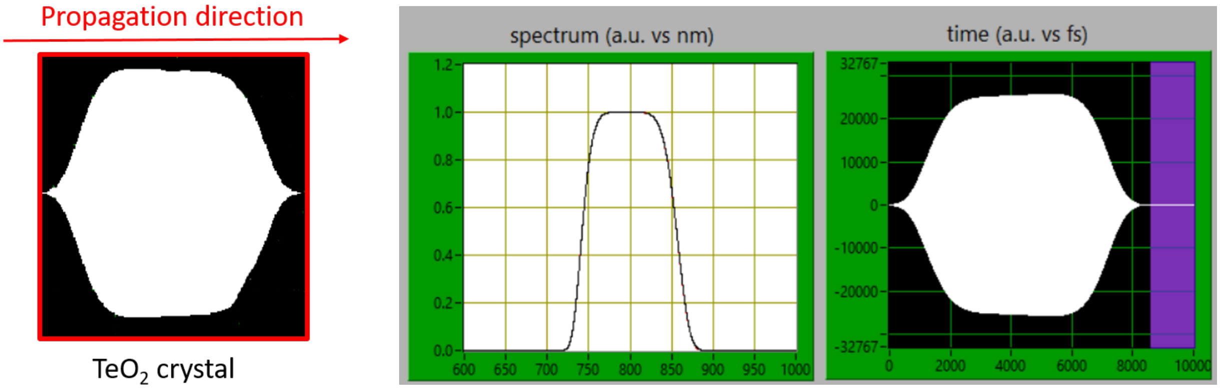


Figure 4.2: Left: acoustic wave position in the crystal when the optical wave propagates through the crystal (acoustic wave unclipped), Right: Equivalent spectrum and time graphs

4.1.3 Effects of incorrect trigger settings

When *Trigger to Laser* is greater than the optimum value (Figure 4.3), or more exactly when *Trigger Delay* is set too short[5], the optical pulse occurs when the trailing part of the acoustic wave is present in the crystal: the wave was launched too early, hence its leading part is missing.

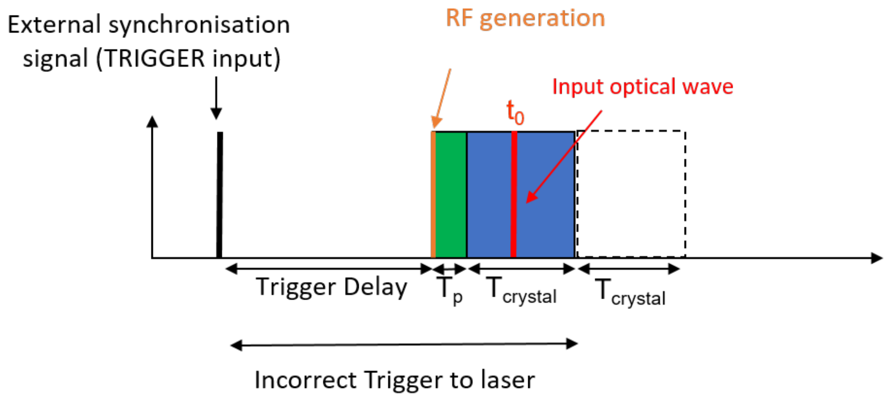


Figure 4.3: Incorrect TRIGGER settings: *Trigger Delay* too short

When *Trigger Delay* is set too long, the acoustic wave is not yet entirely in the crystal when the light pulse arrives. The trailing part of the wave is missing.

4.2 The *Trig&Mode* panel

The Dazzler™software provides a user-friendly interface to enter the delays T_p, *TXtal*, *Trigger to Laser*, *Trigger Delay* correctly based on experiment parameters.
Before opening the *Trig&Mode* panel, check that the single mode operation is selected on the software front panel (one RF cycle is started by one external trigger, see subsection 5.1.7).
The *Trig&Mode* panel opens by clicking on menu *"setup → trig and mode"*.

[5] *Trigger to Laser* depends of the laser construction and is a "given" system constant while *Trigger Delay* can be adjusted

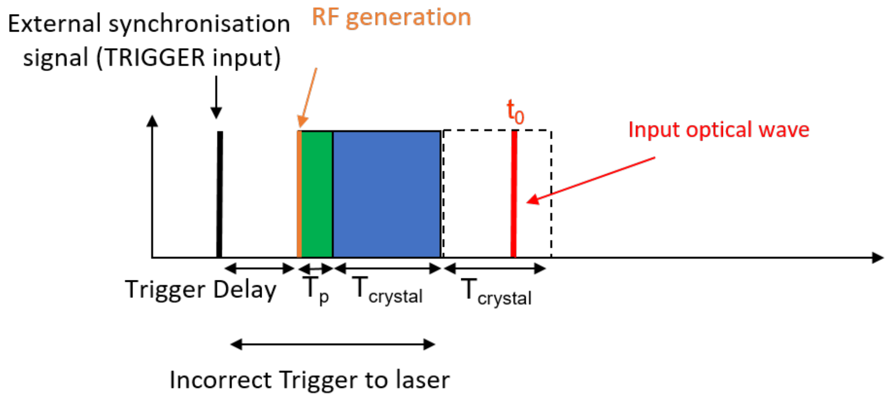


Figure 4.4: Incorrect TRIGGER settings: *Trigger Delay* too long

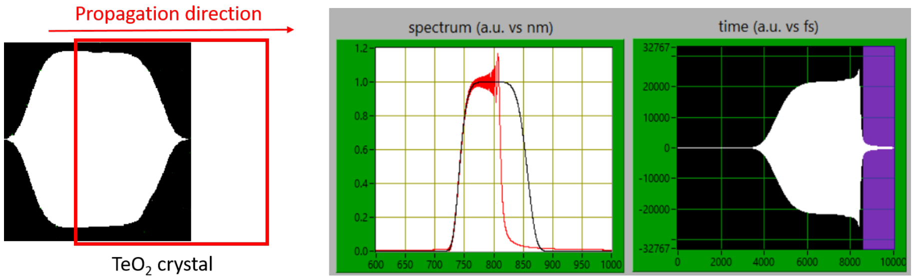


Figure 4.5: *Trigger Delay* too short: Left: acoustic wave position in the crystal when the optical pulse is in the crystal Right: Equivalent spectrum and time graphs

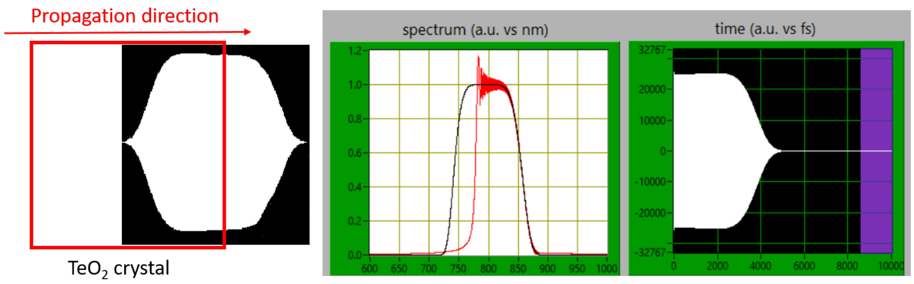


Figure 4.6: *Trigger Delay* too long: Left: acoustic wave position in the crystal when the optical pulse is in the crystal Right: Equivalent spectrum and time graphs

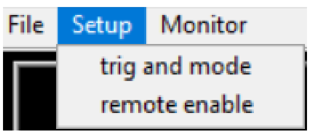


Figure 4.7: *Trig&Mode* panel activation

When the *Trig&Mode* panel is opened for the first time, the warning message shown on Figure 4.8 is displayed. It gives the precision of the trigger delay generation (subsection 4.3.3). To reach this precision level, all waveforms have to be re-loaded after any change in the *Trigger to Laser* control.

WARNING: The *Trig&Mode* panel is associated with a subprocess distinct from the process

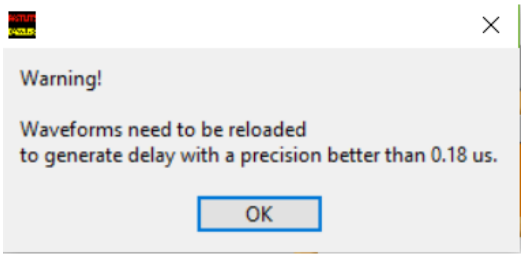


Figure 4.8: Warning message displayed when the *Trig&Mode* panel is opened for the first time

operating the main panel. This subprocess is activated regularly to update the message banner. The ***Trig&Mode* panel should not be left open** during normal operation as it may cause instabilities[6]: thus keep it open during adjustments but do not forget to close it: exit by the left-top cross of the window.

4.2.1 Panel presentation

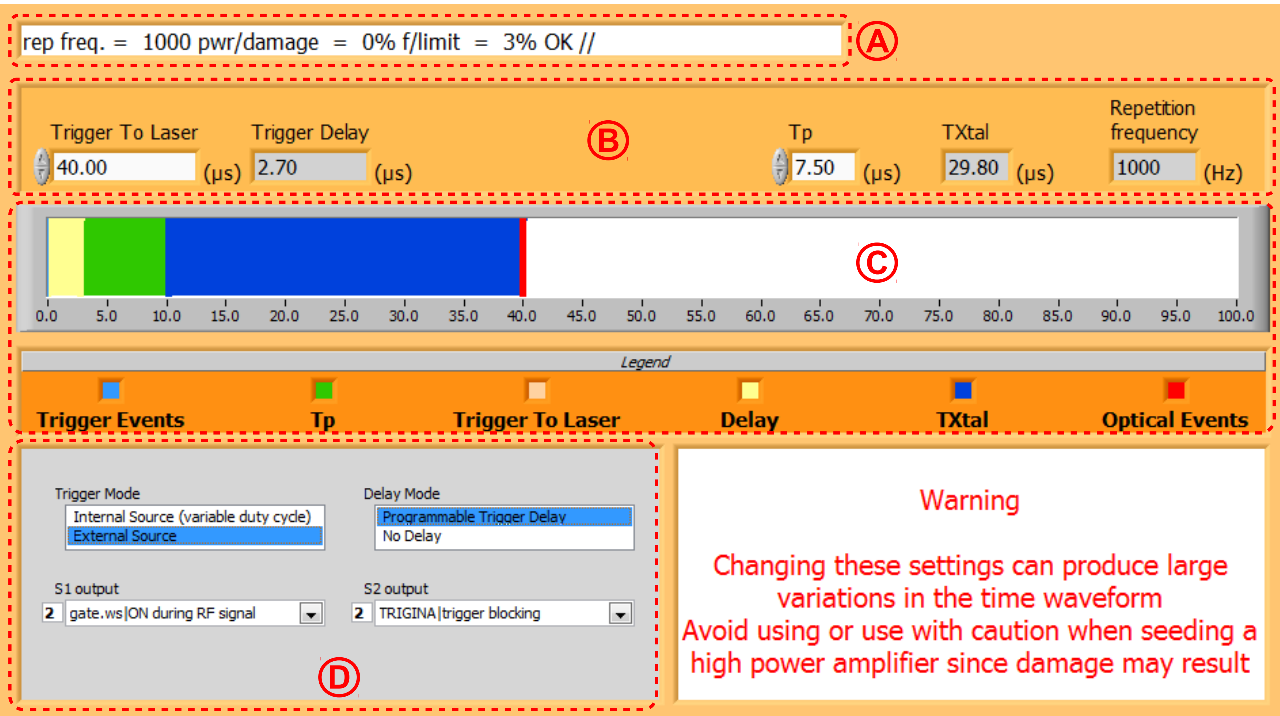


Figure 4.9: *Trig&Mode* panel (WR25 Dazzler™typical values)

The *Trig&Mode* panel features the following parts (from top to bottom on Figure 4.9):

A: a *message banner* situated on the top-left corner, shows the same "polling" message as the one in the Dazzler™main window.

B: *Parameters* that are used to compute delays.

[6]when open, every second, the trigger frequency is read and used to set the hardware delay circuits. As the frequency is measured by counting, the count may vary by 1 or 2 and thus trigger inopportune reprogramming of the delay circuits.

C: A *graph* along with its legend, displaying influence of the different delays on global timing.

D: Some *additional controls* to change the triggering mode and to select the signals available on the different output BNC sockets of the generator[7]. For more details concerning the *S1* and *S2* output signals, please refer to subsection 8.7.3.

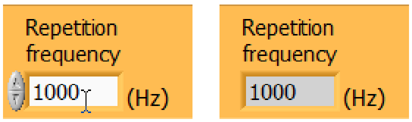
4.2.2 Key parameters

- *Trigger to Laser* represents the delay between the rising edge of the signal connected to the TRIGGER input of the RF generator and the optical event (e.g. *Trigger to Laser* =50μs means that the laser pulse comes 50μs after the trigger edge). The *Trigger to Laser* control *MUST* be adjusted by the user following the procedure described in subsection 4.2.3.

- T_p mainly represents the propagation time of the acoustic pulse from the transducer to its reflection upon the crystal input face. It corresponds to the delay between the RF generation start and the acoustic wave reflection on the input face. Its value usually lies between 3 and 15μs , depending on the Dazzler™cut and the optical alignment. For HR25 Dazzler™systems, T_p =7.5μs . It is advised not to change the default value set in the software.

- *Repetition Frequency* is the frequency of the *Trigger* signal (TRIGGER input).

  This numerical box can be either an indicator or a control. It is a control when Trigger Mode selects `Internal Source (variable duty cycle)` and also when Trigger Mode selects `External Source` and the parameters require *Trig on Previous* mode. The user has to enter the **exact** value corresponding to the laser trigger source, see Figure 4.15 for details.



(a) Control (b) Indicator

When an indicator, the box shows the actual *Repetition Frequency* as counted by the RF generator (4.10(b)).

Figure 4.10: Different *Repetition Frequency* behaviors

When the *Repetition Frequency* item is a control, the input value may differ from the currently measured value. If the measured value leads to significantly different computed timings, a button appears (4.11(a)) to help copy the last measured value in the control and re-compute timings. This copy can also always be obtained by the activation of the context menu (right-click on the *Repetition Frequency* control, 4.11(b)), even if the button is hidden.

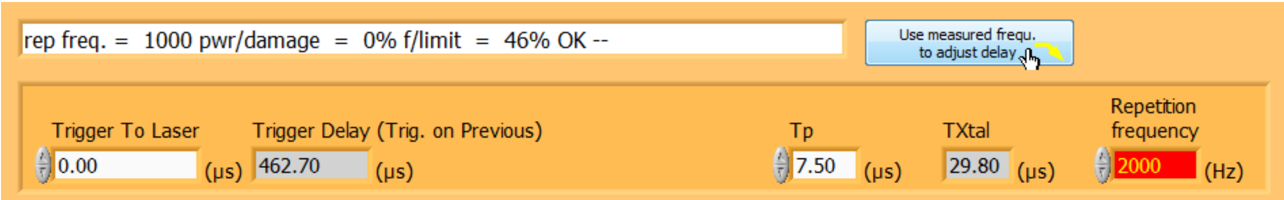
- *TXtal* represents the time needed by the acoustic pulse to propagate between the optical input and output faces. Its value depends only on crystal cut and length, and cannot be modified by the user. The Table 4.1 gives the typical values of *TXtal* for WB25, WR25 and HR25 Dazzler™systems.

- *Trigger Delay* shows the computed optimal delay that will be introduced by the Dazzler™RF unit between the TRIGGER rising edge and the RF generation start. Everytime any of the above controls is modified, optimal *Trigger Delay* is re-computed and displayed.

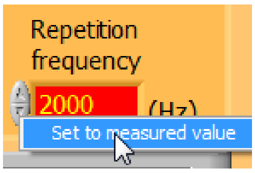
[7]S1 & S2 are always present, newer generators provide S1 to S4, either on the back panel or on the frontpanel for rack mounted equipment.

	WB25 model	WR25 model	HR25 model
TXtal (μs)	23.60	29.80	32.66

Table 4.1: typical values of *TXtal*



(a) Button



(b) Contextual menu

Figure 4.11: *Repetition Frequency* adjustment helpers (WR25 Dazzler^{TM}typical values)

4.2.3 *Trigger to Laser* adjustment procedure

As shown in section 4.1 and section 4.2, the precise synchronization of the acoustic with the optical wave requires that the *Trigger to Laser* value be adjusted with the same accuracy. The following steps explain how to proceed.

1. Set *Trigger to Laser* to the value corresponding to the setup. If necessary, measure it with a photodiode and an oscilloscope.
2. If working in *Trig on Previous* mode, adjust *Repetition Frequency* to the value corresponding to the setup.
3. Send the diffracted beam to a spectrometer (*REMINDER : amplifiers should not be used until the* Trigger to Laser *value is correctly adjusted.*).
4. Set the phase option to polynomial and the "order 3" and "order 4" to zero. Use the "delay" dial to center the signal on the time graph.
5. Increase the second order phase coefficient ("order 2") until the signal covers the full window on the software time graph (Figure 4.12).
6. Measure the diffracted spectrum.
7. Increase the *Trigger to Laser* value until the measured spectrum is truncated. Then, decrease the value until the measured spectrum is truncated again.
8. Set the *Trigger to Laser* value to the mean of these two values.
9. Re-check that the diffracted spectrum is not truncated.

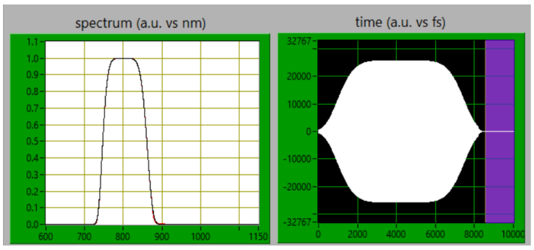


Figure 4.12: Pulse used to adjust the *Trigger to Laser* value.

4.3 Modes of operation

The word "mode" has been overloaded, it is used to loosely qualify various states and operation modes:

1. CONTINOUS versus "Normal" or "single"
2. ONLINE versus OFFLINE
3. Alternate versus MemA or MemB "display"
4. streaming, table driven sequence mode
5. wave cycling
6. *Trig on Previous* versus "normal" triggering
7. No Delay
8. High Repetition Rate

4.3.1 Normal mode

Normal repetition mode is automatically selected when condition Equation 4.1 is verified:

$$Trigger\ to\ Laser\ >= Trigger\ Delay\ + T_{Xtal} + T_p \tag{4.1}$$

Or, in simpler words, the laser system provides a trigger signal *sufficently ahead* of the optic pulse to allow synchronization with adjustment of a short delay (few μs). Signals in this mode are represented on figure Figure 4.13.

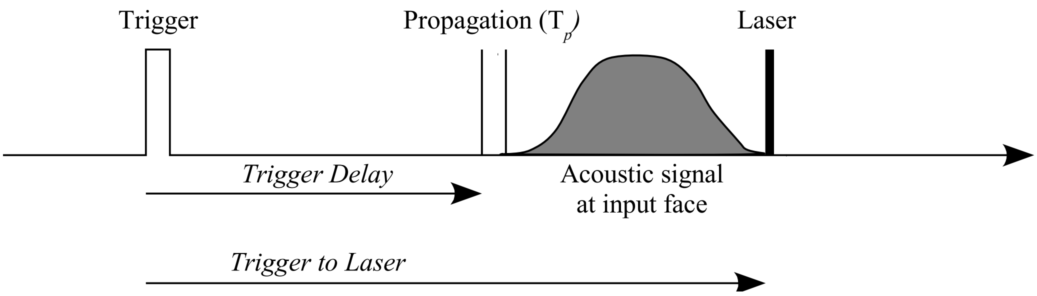


Figure 4.13: Normal repetition mode

Trigger to Laser value must be smaller than the $triggerperiod = (1/RepRate)$. If not, a dialog box is displayed and the warning "Missed Trig (delay)" appears in the *Trig&Mode* panel message bar (Figure 4.14, see Figure 5.19 for more details concerning this warning).

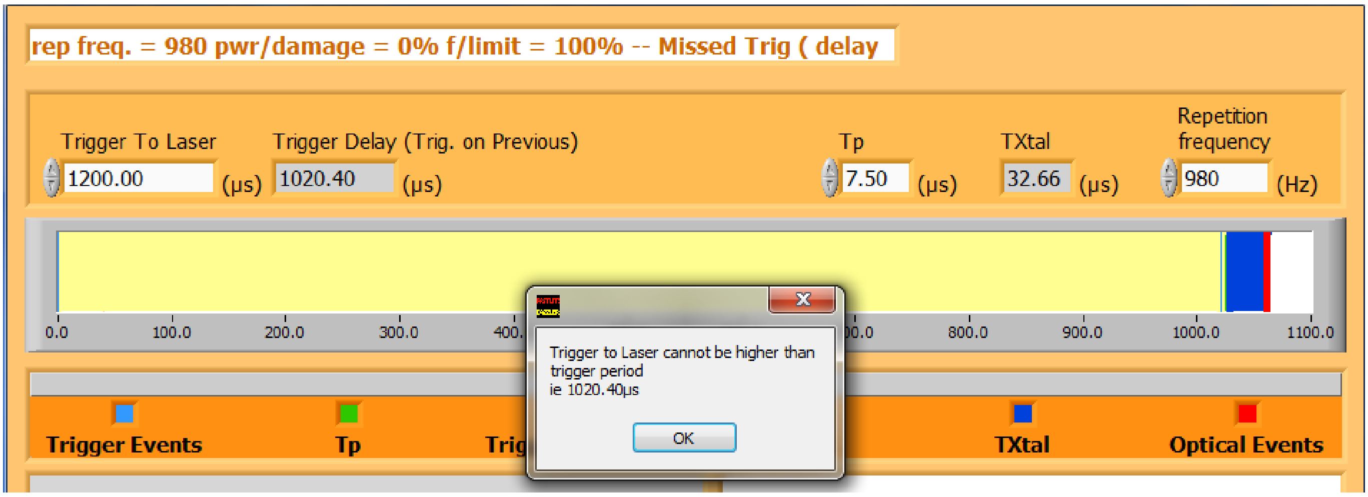


Figure 4.14: Dialog box and warning displayed when the *Trigger to Laser* value is higher than the trigger period.

4.3.2 *Trig on Previous* mode

When Equation 4.1 is not verified, *Trigger Delay* cannot be computed using Equation 4.1. In this case the software automatically switches to the *Trig on Previous* mode. This is indicated in the *Trigger Delay* control label, as shown on figure Figure 4.15.

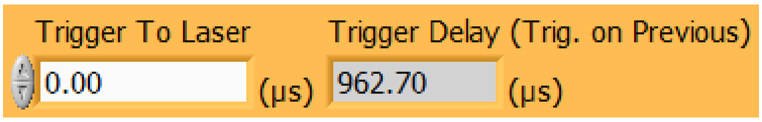


Figure 4.15: *Trig&Mode* panel showing *Trig on Previous* mode controls

In this mode, the trigger used to start delay generation is not the one associated with the diffracted optical pulse, but the previous one as shown in figure Figure 4.16. To compute the *Trigger Delay* value, the trigger period (1/*Repetition Frequency*) is added to the right-hand side of Equation 4.1.

$$\textit{Trigger Delay} = \textit{Trigger to Laser} - T_{Xtal} - T_p + \frac{1}{RepRate} \tag{4.2}$$

Since the laser repetition rate is used by the *Trigger Delay* computation, its value must be set manually by the user. This avoids the delay value to fluctuate with *Repetition Frequency* measurements (see subsection 4.2.2 for details).

4.3.3 Influence of *Trigger Delay* limits

The internal delay generator inside the Dazzler™RF unit has hardware limitations: though these strongly depend on the Dazzler model, the typical range stands from a fraction of a microsecond up to a few milliseconds (for standard HR25 models with V5 boards, values can be between 0.72μs and 5825μs).
When the result of equation Equation 4.2 is outside the generator internal delay range, the software forbids the use of the *Trig on Previous* mode. For a standard HR25 model with a V5

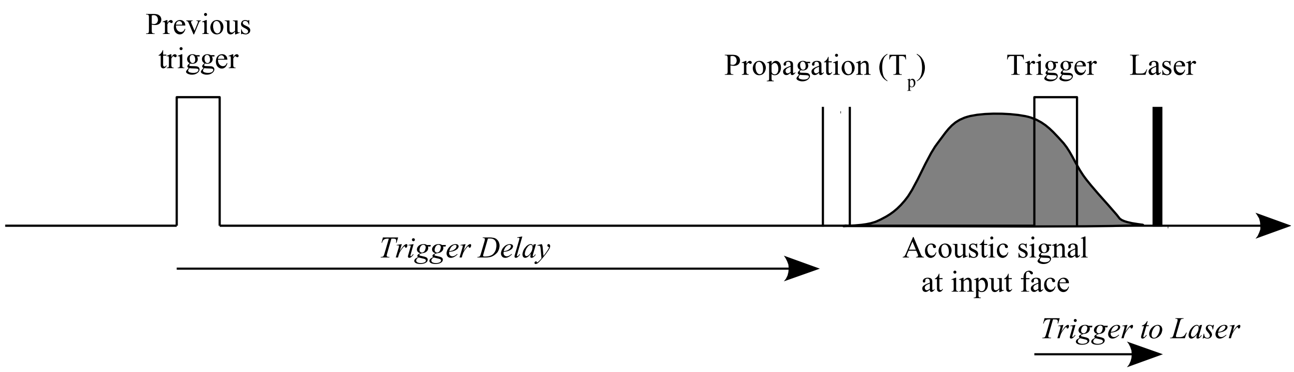


Figure 4.16: Timing in *Trig on Previous* mode

boards, it typically occurs for repetition rates below 171Hz. In this particular case, Equation 4.1 also leads to a *Trigger to Laser* maximum value :

$$\textit{Trigger to Laser}\ _{Max} = \textit{Trigger Delay}\ _{Max} + T_p + T_{Xtal} \tag{4.3}$$

If one tries to input a greater value of *Trigger to Laser* , the Dazzler™software outputs a typical message displayed on Figure 4.17.

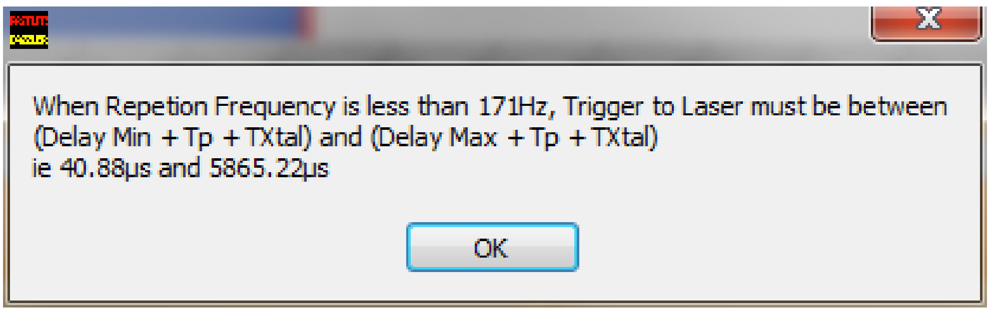


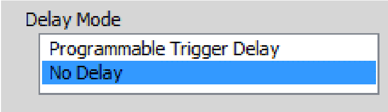
Figure 4.17: *Trigger to Laser* value out of range dialog (HR25 model typical values)

To reach a higher precision level than the one of the internal delay generator, the Dazzler™software adds or subtracts a delay to the spectral phase of the generated waveform. For standard HR25 models with V5 boards, the precision is typically 0.18 μs. Because the software uses the spectral phase of the generated waveform to reach this precision level, all waveforms to be used have to be re-loaded after a change of the *Trigger to Laser* value[8].

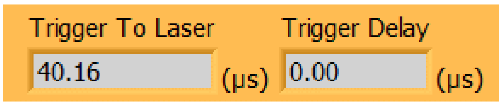
4.3.4 No Delay

If one needs to bypass the Dazzler™RF generator delay circuits, this can be done by selecting the “no delay” mode[9] (figure 4.18(a)). In this case, *Trigger to Laser* must be set to the measured value and cannot be modified anylonger. An external delay generator must be used to provide the trigger pulse to the Dazzler™.

[8] This affects particularly the sequences which are stored in the generator memories
[9] This is the case for systems using the *lowjitter* option.



(a) Mode selection



(b) Fixed Trigger To Laser value

Figure 4.18: "No Delay" mode

4.3.5 High repetition rate

In normal use, there is a different acoustic wave for each diffracted optical pulse. This generally prevents using the Dazzler^{TM}with repetition rates higher than $1/T_{Xtal}$ (time needed to refresh the acoustic pulse in the crystal). For HR25 Dazzler^{TM}systems, this limit corresponds to 30 kHz repetition rate.
It is however possible to run a Dazzler^{TM}at higher optical pulse repetition rates, at the expense of a lower pulse shaping capability and some small phase variations between consecutive pulses. This mode is called "High Repetition Rate", and is switched on automatically when:

$$\left(\frac{1}{RepRate} + Trigger\ to\ Laser\right) \leq (T_p + T_{Xtal} + d_{Min}) \tag{4.4}$$

When "High Repetition Rate" mode is active, a blinking indicator appears in the upper right corner of the *Trig&Mode* panel. The number of optical pulses diffracted for each acoustic cycle is then shown in the N indicator. The graph along with its legend are updated (Figure 4.19).

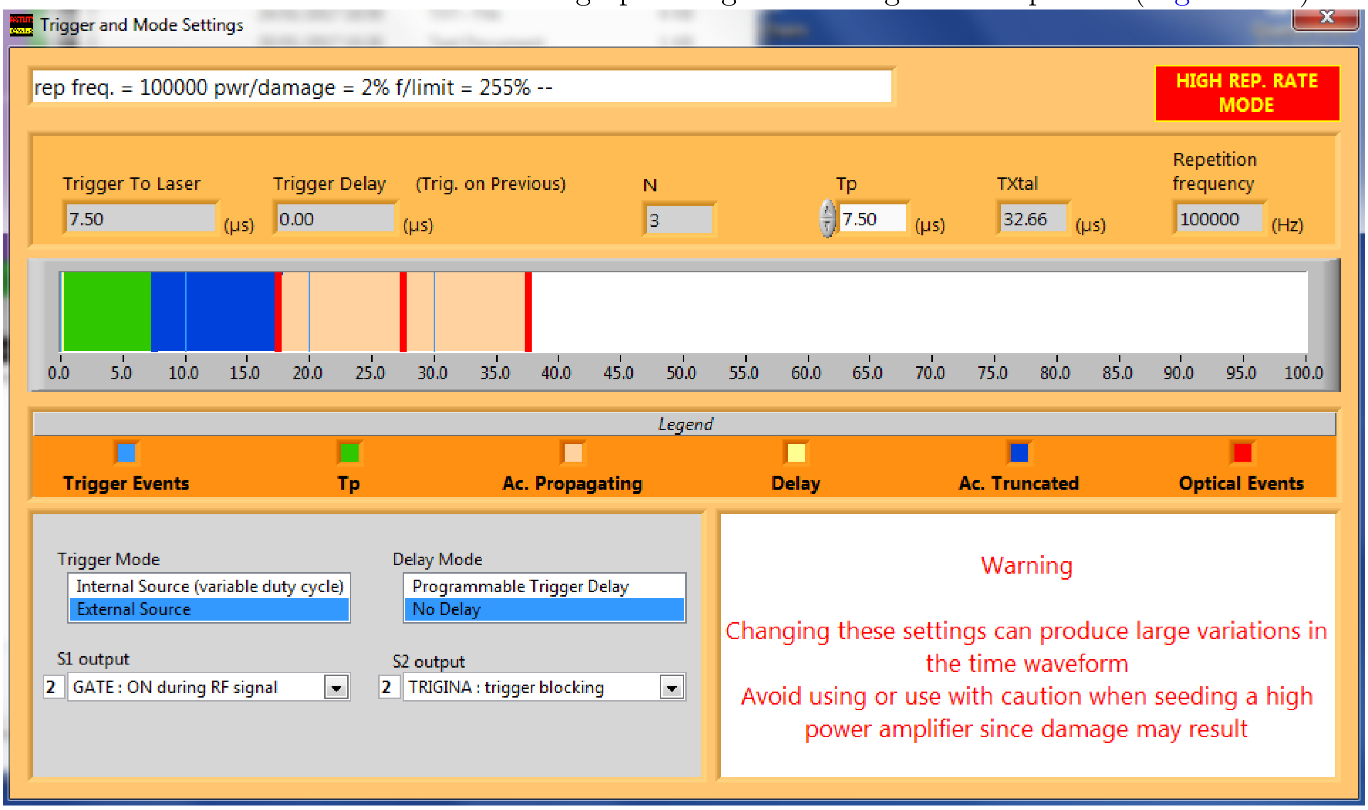


Figure 4.19: "High Repetition Rate" mode - (HR 25 Dazzler^{TM} model typical values)

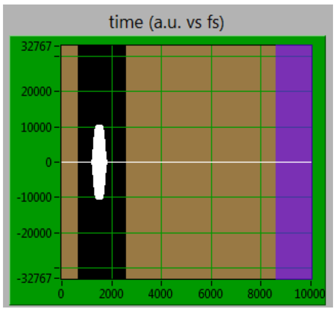
The acoustic cycle duration in this mode is given by :

$$\tau_{Ac} = N \cdot 1/(Repetition\ Frequency\ ) \tag{4.5}$$

Considering the instant when the acoustic pulse diffracts its first optical pulse, it could not be in the crystal $(1/\textit{Repetition Frequency}\ )\mu$s before, or it would have interfered with the previous cycle. In the same way, it should not still be in the crystal τ_{Ac} μs after without interfering with the next cycle. This leads to loss in pulse shaping as the acoustic pulse maximum length $\Delta\tau_{\max}$ (Equation 4.6) is shorter than T_{Xtal}/N.

$$\Delta\tau_{\max} = \frac{1}{\textit{Repetition Frequency}} - \left(T_{Xtal} - \frac{N}{\textit{Repetition Frequency}}\right) = \frac{N+1}{\textit{Repetition Frequency}} - T_{Xtal} \tag{4.6}$$

The pulse shaping capability loss is shown by yellow bars on the time graph of the Dazzler™ front panel (figure Figure 4.20) see below.



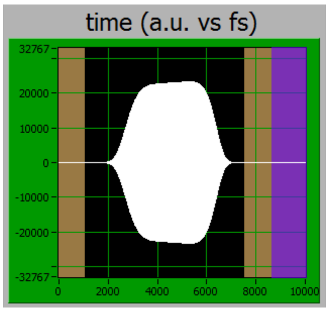


Figure 4.20: Examples of shaping losses in "hirep rate"

CHAPTER 5

Software & Operation

5.1 Front panel

When starting the Dazzler™ software, the following window appears:

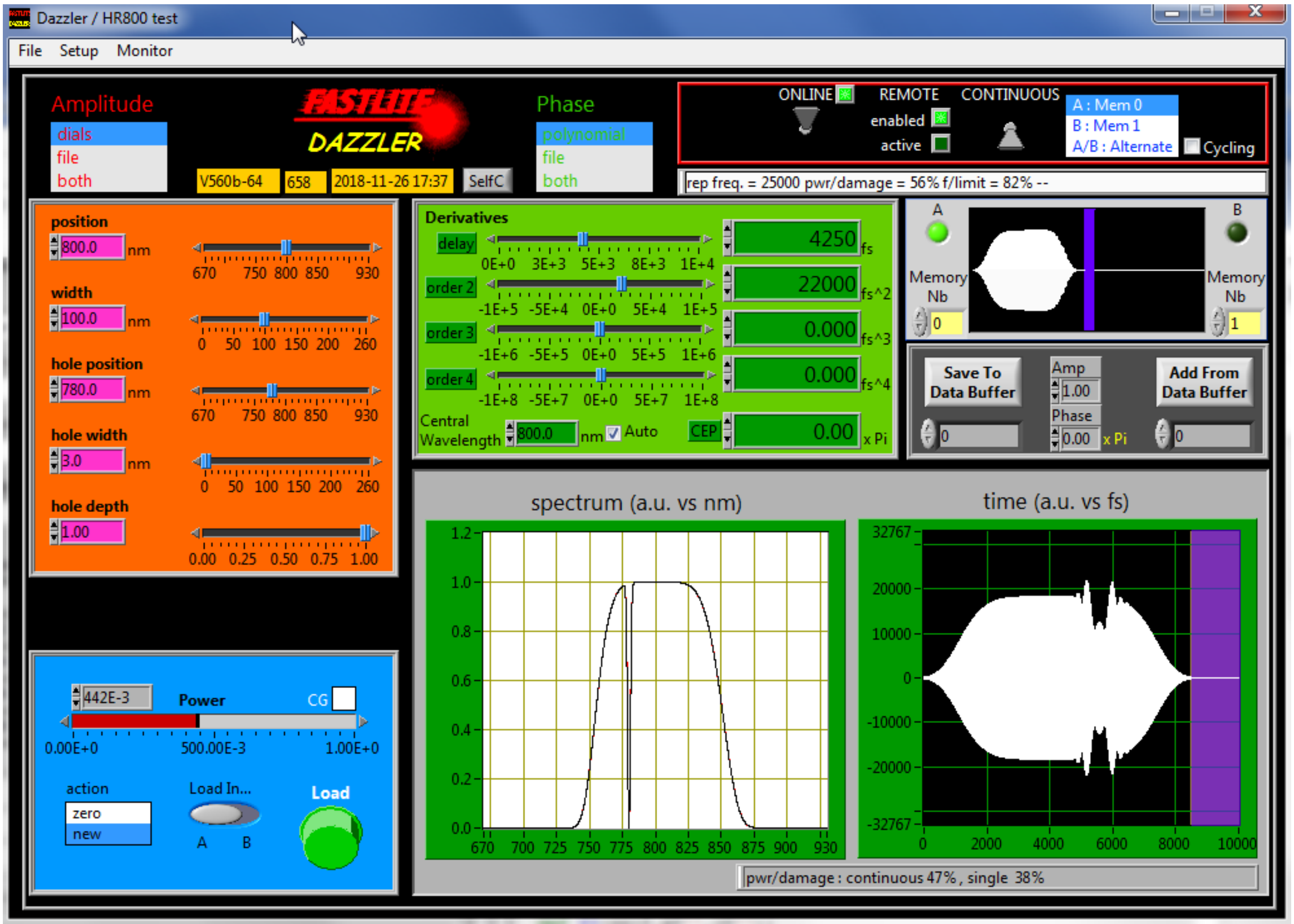


Figure 5.1: Dazzler™ GUI software front panel

5.1.1 Blue area: power, constant gain, zero, load wave in memory

Power: This dial controls the output RF power. It is normalized so that the maximum is 1. Because of saturation phenomena it is advised to use the device at low power whenever possible. Operating at low power gives more linearity but reduces the dynamic range.

Constant Gain (CG check box)

Most of the time this box is left unchecked. In this case, the peak-to-peak amplitude of the signal is normalized to a value determined by the power control. When it is checked it keeps the global gain of the diffraction constant when the phase controls are changed. For instance, when adding 3rd order phase, the signal in the time graph gets distorted and shows a peak. If you use the Constant Gain option, the diffraction remains the same despite this peak. Without the Constant Gain, the diffraction should have decreased because the maximum power corresponding to the peak is kept constant and thus the average value decreases.

In other words, without Constant Gain, the diffraction efficiency changes with the phase control (because of peak values and normalization). And with Constant Gain, the diffraction efficiency remains the same independently of phase control, except if the signal amplitude is so large that saturation would occur, in which case loading is prevented. When using constant gain, check that the signal amplitude does not exceed the saturation limit on the time graph as shown in Figure 5.3.

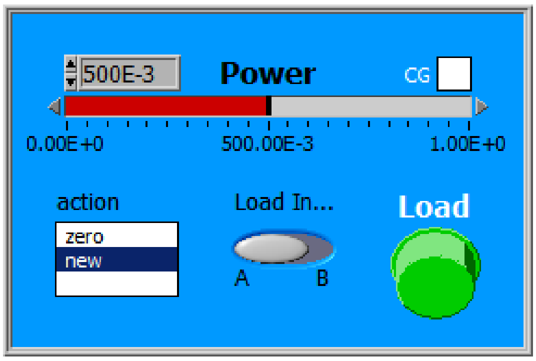


Figure 5.2: Blue Area : Power and Load

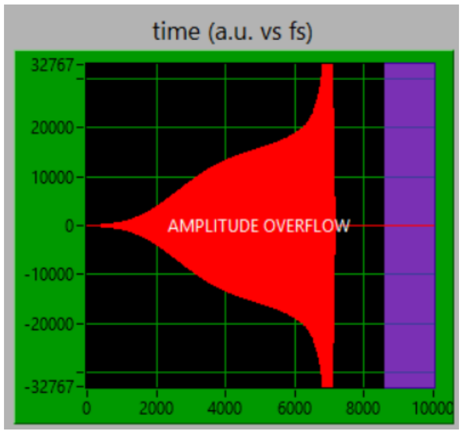


Figure 5.3: Saturation occuring with CG

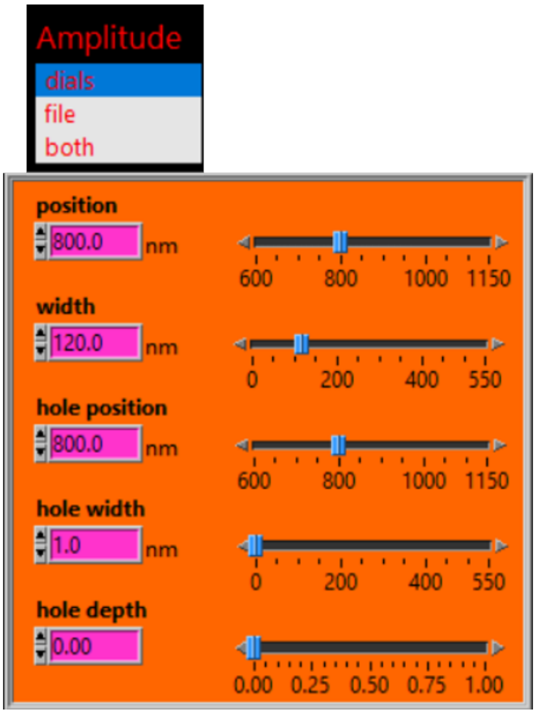
Launch acoustic wave : LOAD

Until this button is pushed, any change in the settings of the controls only affects the spectrum and time graphs shown by the software (subsection 5.1.5). When the LOAD button is pushed, the RF generator receives the waveform information. The loaded wave is shown in the loaded waves display (subsection 5.1.6) and is stored in RF generator memory slot pointed by A or B ("Load In.." selector). The RF output signal looks like the curve represented on the loaded waves graph.

action slider

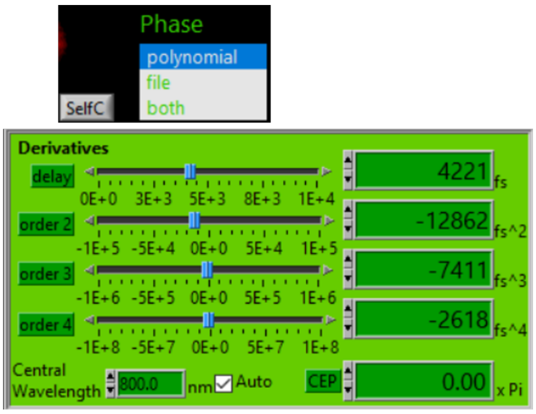
If the action slider "Zero" is selected the output signal is set to zero **without** affecting the current wave parameters. Clicking on the LOAD button zeroes the output buffer (selected memory bank). When New is selected, the waveform represented on the time graph is loaded when clicking on the LOAD button.

5.1.2 Orange area: spectral amplitude control



The spectral amplitude is programmed either by a text file or by the dials of the orange area, or a combination thereof. When the Amplitude selector is set to `dials`, the spectral amplitude is defined by the controls of the orange area. The principle of this shaping is to combine a supergaussian spectral shape with an optional hole at a given position: the exact formulas are described in section 2.3. The selection `file` makes the spectral amplitude defined by the text file `amp.txt` (see subsection 5.4.1 for format description) which resides in the default directory `C:\dazzler\data` (see section 5.3.1).
The selection `both` programs an amplitude which is the product of the dials result and the file result.

5.1.3 Green Area: spectral phase control

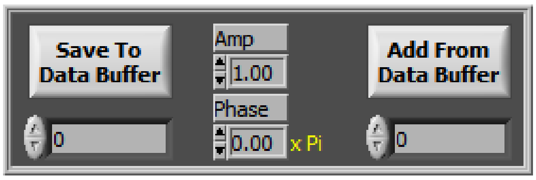


The spectral phase selector is similar to the amplitude selector control. When `polynomial` is selected, the dials program a polynomial phase function with respect to the specified central wavelength. This central wavelength is automatically following the center position of the amplitude shape when the "auto" box is checked. It can be set arbitrarily if auto is unchecked.
The `file` selection generates a spectral phase from the file `phase.txt` (see subsection 5.4.1 for format description) residing in the default directory `C:\dazzler\data` (see section 5.3.1).

When `both` is selected, the resulting spectral phase is the sum of the polynomial result and the file result. The formulas are described in section 2.3.

When the SelfC (Self Compensation) button is pressed, the *order2*, *order3* and *order4* controls are filled with the negated coefficients of the dispersion introduced by the crystal in ordinary polarization mode. With this setting, the Dazzler device is dispersion free, with the programmed diffraction induced phase compensating the natural dispersion of the crystal.

5.1.4 Grey Area : Waveform Combination



This panel is used to generate a waveform by the arithmetic combination of the current waveform, as defined by the current panel controls, and of previously stored waveforms.

The current waveform may be stored in a data buffer[1] chosen by the index number below the "Save To Data Buffer" button, yielding $S_{saved}(\omega)$. When the "Add From Data Buffer" button is not activated, the arithmetic combination is disabled: i.e the waveform is simply the one defined by the panel controls $A(\omega).e^{i\cdot\phi(\omega)}$. When the "Add From Data Buffer" button is activated, the resulting waveform is computed as:

$$S(\omega) = A(\omega) \cdot e^{i\cdot\phi(\omega)} + \boldsymbol{a} \cdot e^{i\cdot\boldsymbol{\pi}\cdot\boldsymbol{\phi}} \cdot S_{saved}(\omega)$$

where $S_{saved}(\omega)$ is the signal saved in the memory buffer defined below the "Add From Data Buffer" button. The values of the "Amp" (for Amplitude) and "Phase" controls correspond respectively to $\boldsymbol{a}$ and $\boldsymbol{\phi}$ in the above formula (see section 2.3).

For example, in order to generate two identical pulses separated by a given delay, proceed as follows :

1. set the parameters for a single pulse
2. press the save button with the memory buffer value set at 0
3. shift in time by changing the delay in the green area
4. set the "Amp" control at 1 and the "Phase" control at 0
5. press the "Add From Data Buffer" button with the memory buffer value set at 0

To create a third pulse, continue as follows :

6. press the save button with the memory buffer value set at 1
7. deactivate the add waveform button
8. shift in time by changing the delay in the green area
9. press the "Add From Data Buffer" button with the memory buffer value set at 1

5.1.5 Graphs

Spectrum (a.u. vs nm)

This graph represents the amplitude response of the filter ($|H(\omega)|$ defined in section 2.1.3). It shows out two curves: one black (smooth) which represents the programmed spectral amplitude,

[1]program internal memory, not to be confused with the hardware generator internal memory slots

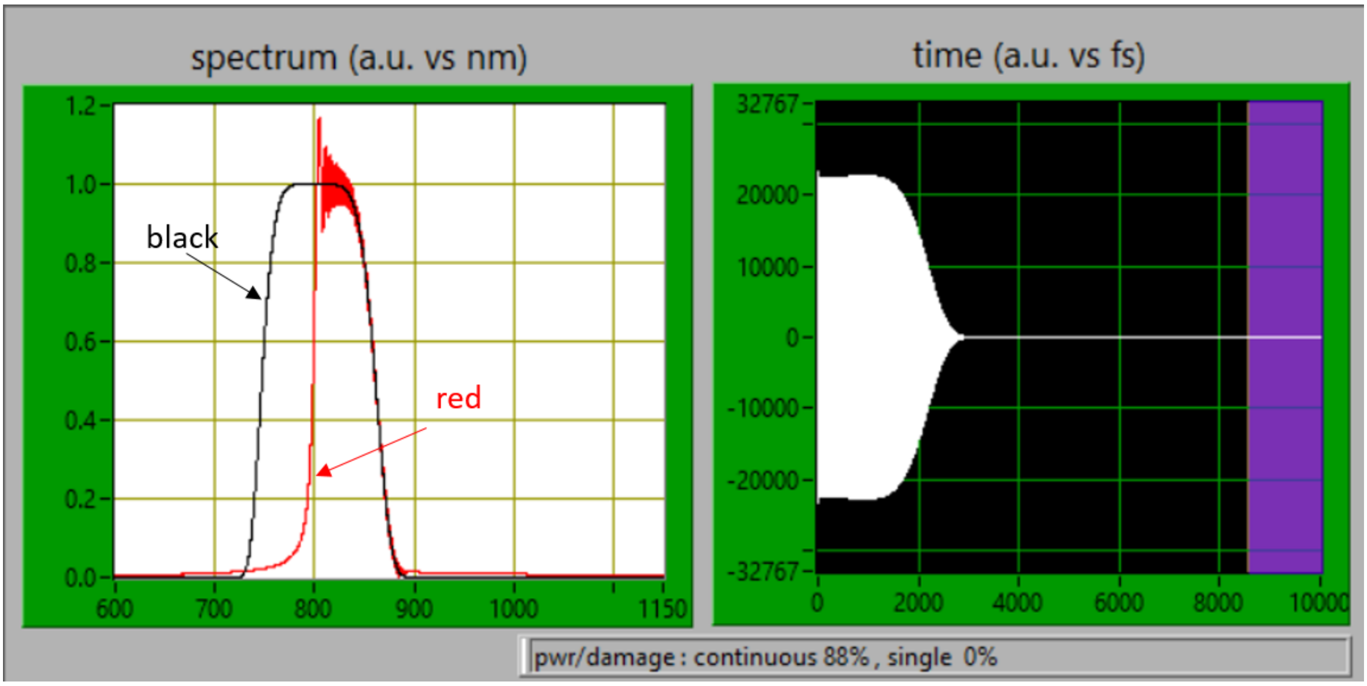


Figure 5.4: Spectrum and Time Displays

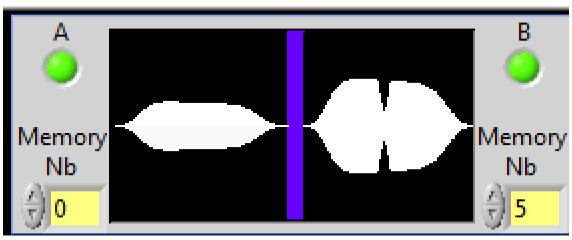
one red (oscillating) which includes the time gating of the crystal. Due to the finite length of the crystal, the spectrum actually generated corresponds to the red curve. These two curves should be superimposed for proper operation.

Time (a.u. vs fs)

This graph shows the simulated optical impulse time response of the filter vs fs ($\texttt{Re}(h(t))$ defined in section 2.1.3). It allows to check if the signal is entirely in the time gate (delimited by the purple rectangle), and if the distortion due to amplitude or phase corrections is not leading to high peak power (implying loss of spectral resolution, non linearities).

REMARK *Artefacts of Moire type could appear on the signal because of the resolution of the screen, therefore do not always trust small fluctuations or details.*

5.1.6 Loaded waves



This small display shows the RF waves currently loaded in the two RF generator memory slots pointed by A and B. The wave stored in memory slot A is displayed on the left side. The one stored in memory bank B on the right side. The *A* indicator lights up when the wave stored in memory bank A is played.

The *B* indicator lights up when the wave stored in memory bank B is played. The graph shape is similar to the time display discussed previously, except that its display is in the acoustic time domain instead of the optical time domain, which leads to some distortion due to the following factors :

1. spectral amplitude corrections for the RF analog response,
2. optional time corrections for the acoustic diffraction pattern,
3. optical dispersion of the ratio α between optical and acoustic frequencies leading to a non linear correspondence between them.

5.1.7 Machine controls

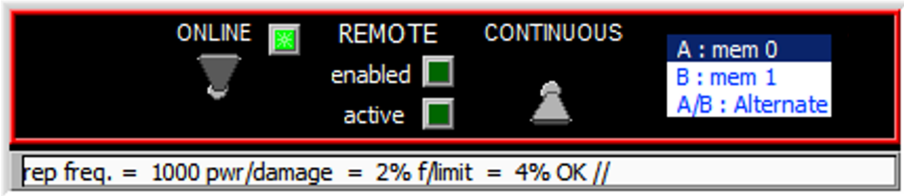


Figure 5.5: Machine Controls

The Machine Controls area contains indicators and switches to monitor and control the activity of the RF generator.

When the "online" switch is down (ie. offline), the software operates in "offline mode" without communicating with the RF generator: this is useful to prepare/simulate operations while not connected to the generator.

When the "online" switch is activated (ie. flipped up), communication with the RF generator is initiated and if successful, the "online" indicator lights, showing that the software operates in "online mode". When in "online mode", the generator is periodically interrogated and the result of this polling process is displayed in the poll message text line, see Figure 5.15. This activity is shown in the message with the cycling every second of the last two characters between the following: `||` `\\` `--` `//`.

The information shown is the actual trigger frequency[2] rounded to the lower integer and the status with respect to acoustic damage. While this banner message is reflecting current operation values, a similar message banner below the spectrum and time graphs (subsection 5.1.5) is showing values which would be obtained if the waveform defined by the current control settings were to be loaded.

The "REMOTE ENABLED" indicator shows whether the system can be remotely controlled using the **text based interface** (setup menu → remote enable option activated). The "REMOTE ACTIVE" indicator lights up in green every time a remote control request is being processed; it lights up in red whenever there are errors in the remote control request. Please refer to chapter 6.

[2]The measurement is based on counting all triggers in a one second period.

1. the SINGLE mode which is the normal operation mode when one RF cycle is started by one external trigger.
2. the CONTINUOUS mode reserved for low power and alignment. As soon as a RF cycle is finished, another one is started. The external trigger is only used to start the generation, and to re-synchronize.
3. the list on the right side is a choice selector (by clicking) :

A: RF from A memory,

B: RF from B memory,

A/B: Alternate switches between A and B at each trigger (information on current memory can be obtained by signal HIWHENA available on the S1 output).

5.1.8 Damage prevention

The acousto-optic crystal assembly can only withstand a limited RF power, the transducer damage threshold being the main limit. The transducer can tolerate a maximum instantaneous peak RF power which is much higher than the average power[3].

The Dazzler™software is designed so that, in most cases, user actions which would lead to excessive power will be detected and blocked before the generator condition is actually changed.

- the top right message banner (Figure 5.6) shows **actual values**: the trigger frequency, alarms and warnings. The `power/damage` ratio value reflects the current RF power compared to the maximum allowed power for the currently active waveform. The parameter `f/limit` reflects the ratio of the measured repetition frequency over the maximum possible repetition rate, depending on trigger delay settings.

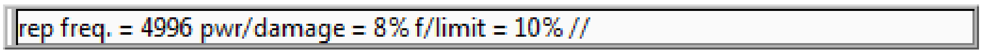


Figure 5.6: Actual average power ratio and signal truncation due to timing

- the message text box at the bottom right part of the main panel displays a **simulation**. Based on the current trigger frequency (1/*TXtal* frequency for continuous mode) and the current software control settings, the average power, expressed as a ratio of the crystal power limit are shown in the message banner (see Figure 5.7).

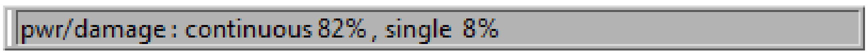


Figure 5.7: Simulation of current wave average power ratio

A percentage above 100% would lead to an excessive RF average power. In this case, the software prevents the user from loading the current waveform (Figure 5.8).

[3]the HR 25 tolerates 50W peak and the average power should not go above 3W.

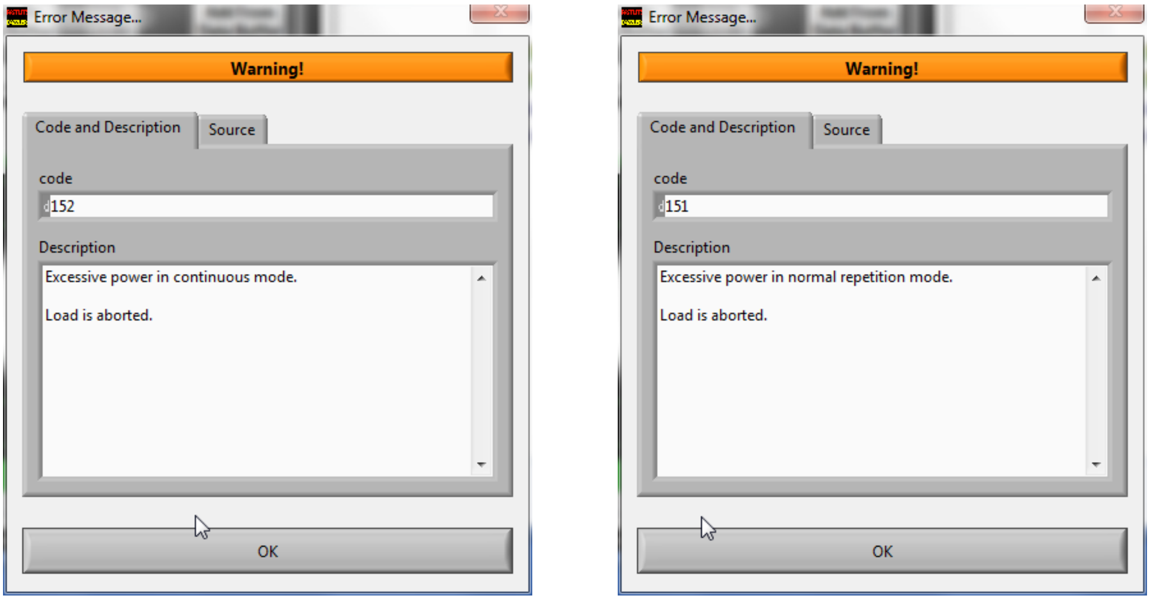


Figure 5.8: Warning messages prevent burnout when loading

When changing the operation mode from single to continuous or switching playable waveform between A and B, an error message appears if excessive RF power would be applied (Figure 5.9). The mode change will be aborted.

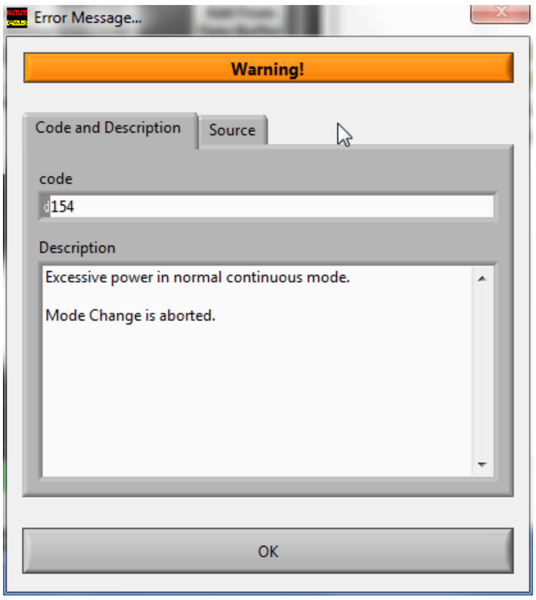


Figure 5.9: Warning messages prevent burnout when changing mode

Each wave sent to the generator contains meta data that gives information on the power damage threshold and the minimum time period in which one cannot send another RF waveform to the crystal without reaching this threshold. Any trigger occurring during this time period is ignored and a missed trigger warning appears (Figure 5.10).

It is possible to visualize the signal corresponding to this minimum time period using the S2 or S4 generator output (PROTECTP see Figure 8.7.4). This security prevents to send excessive

Figure 5.10: Missed triggers due to excessive power

average power to the crystal when the trigger repetition rate is changed outside the software during the experiment.

Remarks on B & Alternate Use: in these cases of operation, the software chooses the worst case between A and B.

5.2 Menu bar

5.2.1 File Menu

This menu allows storage and retrieving of waveform parameters (i.e. panel settings). This is done with the traditional `open, save_as` and `save` items.

To ease operation, the items `save_default & restore_default`. The `save_default` menu is equivalent as saving settings on exit: it will save the current waveform and the trigger settings. `restore_default` will only restore the current waveform. Trigger settings cannot be restored in this way. The information is kept in the parameters directory (section 5.5).

The menu item `exit` stops the program.

5.2.2 Setup menu

`trig and mode`	opens the *Trig&Mode* panel, see section 4.2
`remote enable`	enables/disables the response to remote requests, see chapter 6
`sequences control`	*(optional)* opens the sequences control panel for Dazzler™ models with the "sequence mode" option

5.2.3 Monitor Menu

`configuration`	shows various information of the Dazzler™ system, release information on hardware, firmware and software, diagnostics, alarms,... (see subsection 5.2.4)
`adjust PLL`	*(optional)* opens the adjust PLL settings panel for Dazzler™ modes with Low Jitter option (see specific notes)
`maintenance`	operates diagnostics (to be used under instructions from FASTLITE) (see subsection 5.2.5)

5.2.4 Monitor configuration

On a click on *configuration* the *Monitor* Menu opens the panel shown in Figure 5.11. It contains useful information for remote diagnostics[4]:

- the used I/O Visa/COM port,
- the hardware setup (*Hardware Description* zone),
- the microcontroller software (*Micocontroller Software* zone),
- the presence of alarms and their descriptions (*Alarms* zone),
- the path to the parameters folder (*Parameters Path* zone),
- the path to the 'default directory' folder (*Data Path* zone, see subsection 5.3.1),
- the RF generator configuration (Sampling Frequency, Nb of Samples, DAC Latch,etc)

When asking for support to after-sales service, a screenshot copy of this window will be appreciated as it directly contains these important points:

- the Dazzler™system option: T4 (blue rectangle),
- the software version: V550b-64 and its compatibility with 32 or 64 bit OS versions (green rectangle),
- the RF generator board version: V5.5 (red rectangle).

5.2.5 Monitor maintenance

Clicking on `maintenance` in the *Monitor* Menu opens Figure 5.12. It is used

- to switch to a different parameter set,
- to provide interfaces for options which are under development,
- to upgrade calibrations using text files,

[4]this information varies significantly with the releases of hardware, firmware and software...

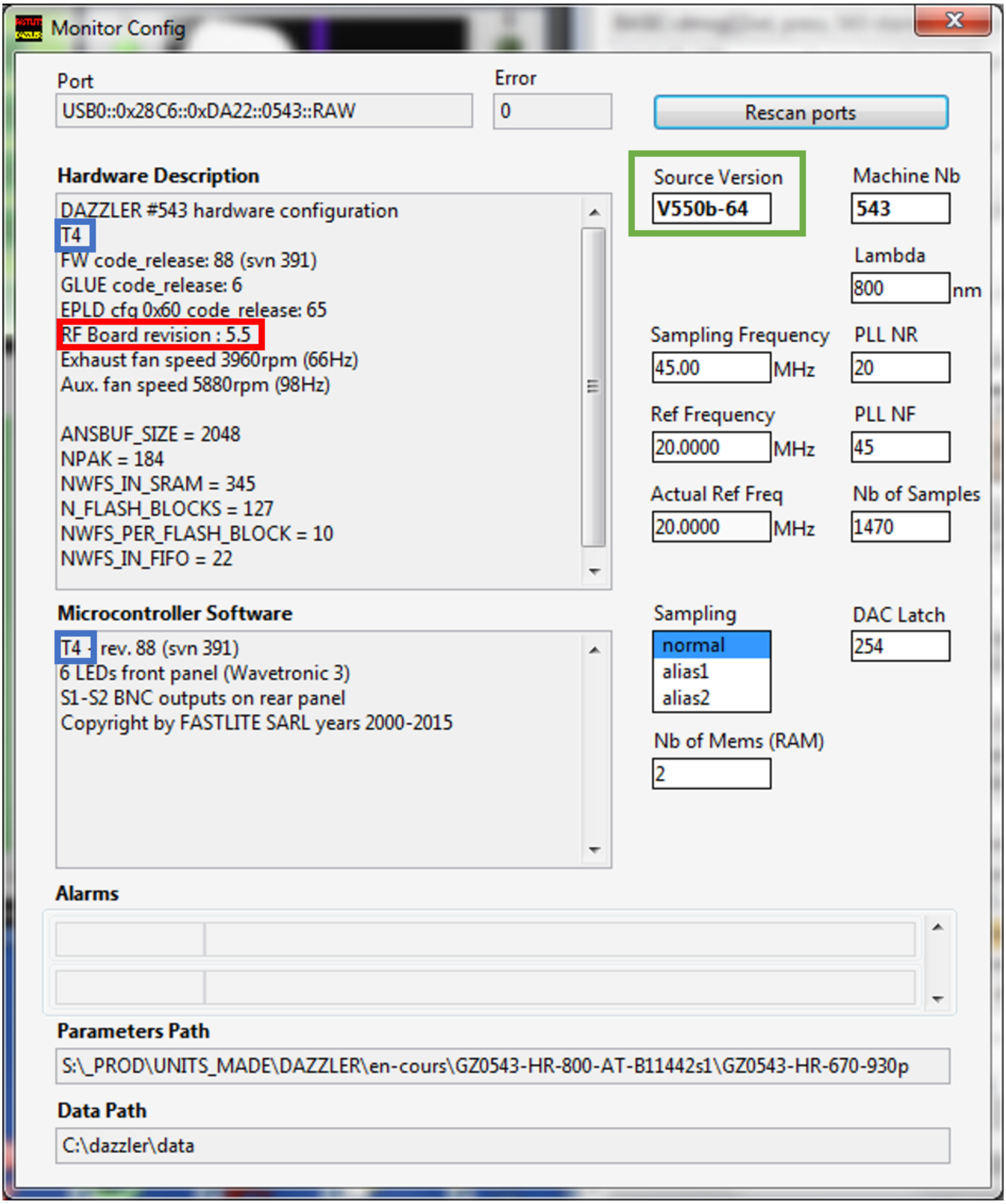


Figure 5.11: Monitor configuration panel

- to force serialization of actions by stopping the "poll" (debugging),
- to access low level commands of the "on board" microcontroller.

This panel must not be used without instructions from FASTLITE .

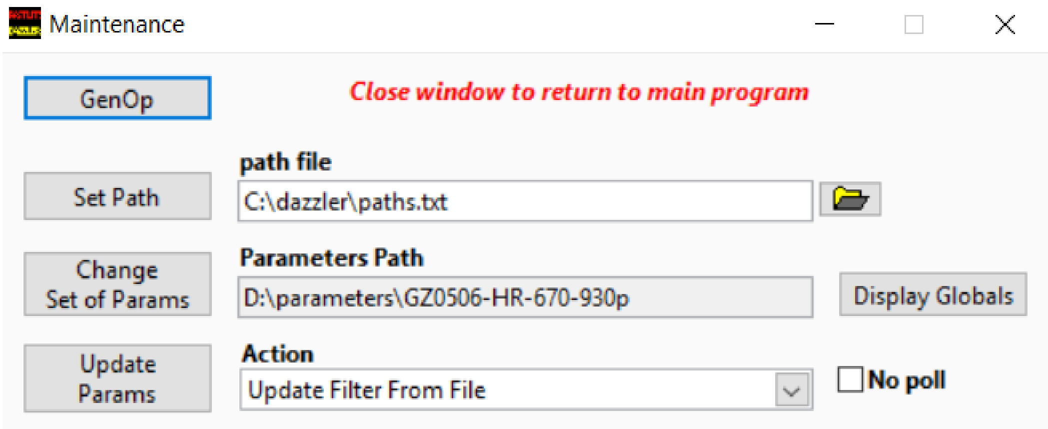


Figure 5.12: Monitor maintenance panel

5.3 Files, paths and file formats

The Dazzler program uses various files for its operation. This section describes these files and their locations.

5.3.1 Default directory

For software version V500i and higher, the installation procedure defines the default directory by adding a section in the .ini file. Previous software versions used the directory where the executable was located (`C:\Program Files\Dazzler`), but Windows 7 and following Windows versions added write protection to system folders, hence it was no longer possible to write to `C:\Program Files\Dazzler` without escalating to admin privileges. The subtree `C:\dazzler` is given `rw` access to everyone during the installation, thus solving the permissions problems.

The 'default directory' is by default `c:\dazzler\data` for a single generator, and `c:\data-1` and `c:\dazzler\data-2` for installations with 2 Dazzlers.

In single Dazzler installations, the 'default directory' is defined in the INI file which filename is the same as the excutable file, e.g.:

```
C:\Program Files\Dazzler\Dazzler-V560b.ini
C:\Program Files\Dazzler\Dazzler-V560b.exe.
```

A section like below is present in the INI file.

```
[Dazzler-V560b]
DefaultDir=C:\dazzler\data
```

The INI file may change this default to a different folder[5]. Users requiring to change the defaults

[5] for network operations, to avoid "opening" the system volume

in the INI files must edit them with Administrator write access. The Dazzler program processes the INI file once, on startup.

5.3.2 Data Files

Brief description of the files used by the Dazzler program, mostly residing in the 'default directory' (see subsection 5.3.1).

- `amp.txt` and `phase.txt`, located in 'default directory' . These files are used to specify spectral data through numerical arrays (see subsection 5.1.2, subsection 5.1.3 and subsection 5.4.1).
- `request.txt`, used for the remote file operation protocol (see subsection 6.1.2) is located in the 'default directory' .
- `wave files`, used with the commands `open/save` and with the remote operation (see section 5.4).
- `params.txt`, located in the default directory. It defines the absolute filepath to the parameters' folder (section 5.5). The parameter folders can be located anywhere.
- `wave.txt`, **located in the parameters' folder.** It describes the waveform which appears when starting the Dazzler program.

5.3.3 C:\dazzler

This folder `C:\dazzler` has been required since the remote access was introduced (2003). This folder holds information which must be available from anywhere. Present content:

- folder `data` is the 'default directory' for single Dazzler installations.
- `paths.txt` written by the Dazzler program on remote enable changes (see subsection 6.2.4).

5.4 Wave files

These files are used to save shaping parameters. It is the file format used when using the *load*, *save* and *save as* items of the file menu. They are also used to provide changes when controlling the software remotely (see section 6.2).

Each line in this text file describes the state of a control on the front panel. The list of legal controls follows in Table 5.1 (the names and syntax can also be deduced from the `wave.txt` present in the parameters folder).

The control definitions are essentially self-explanatory, except for the `amplitude` and `phase` selectors, which describe the mode of operation (polynomial=0, dials=0, file=1, both=2). The `auto`, `addwaveform` and `cg` parameters are 0 if unchecked and 1 if checked.

amplitude=0	position=8000	width=1600
hposition=8000	hwidth=100	hdepth=00
phase=0	delay=42000	order2=-12862.37
order3=0	order4=0	centralwl=8000
auto=1	addwaveform=0	frommemory=0
combamp=10	combphase=00	power=0.100000
cg=0	lmemory=0	cep=00

Table 5.1: wave.txt Table of controls

Except for the `wave.txt` file used to save program defaults, it is not mandatory to provide value for every control. Only those named in the text file are changed, others will be kept constant (e.g. one line of the form `position = 780.0`).

After this first section, the wave text file may contain `#amp` and `#phase` sections which specify numerical amplitude and phase. If present, the data in the sections are used to overwrite the `amp.txt` and `phase.txt` before computing the new waveform (see subsection 5.4.1 for format).

5.4.1 amp.txt and phase.txt file format

Both arrays describing spectral amplitude and phase should be written in the files as two column arrays with the "`tabulation`" character as separator (Excel and LabVIEW spreadsheet standard `.txt` format).

- First column : wavelength in nm in increasing order
- Second column : amplitude or phase value for that wavelength

Units for the phase are radians, units for the amplitude are arbitrary (only the relative values are relevant).

Note that these files can be embedded in the `wave` files, using separators #amp or #phase (see section 5.4).

Calculation

The spectral amplitude $A_{file}(\omega)$ and spectral phase $P_{file}(\omega)$ are interpolated with respect to ω, between the points given in the file. $A_{file}(\omega)$ is linearly interpolated, while $P_{file}(\omega)$ is interpolated by a spline. For wavelengths outside of the range found in the file, the applied values are those at the boundaries, eg. for a wavelength of 600nm, a value of 0.3 in the next example.

Calculation example

700	0.3
750	0.4
800	0.8
850	0.6
900	0.2
1000	0.1

The wavelength values λ are converted into optical frequencies values $\omega = 2\pi C/\lambda$ to generate $A_{file}(\omega)$ and $P_{file}(\omega)$.

5.5 Parameters

The Dazzler^{TM} application software uses text files to keep data related to the complete system, like the crystal parameters, 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. One 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**.

5.5.1 Parameter files

Location and names of files

Parameter files are generally kept in a different directory than the Dazzler^{TM} software itself. This allows to store them on a different partition than the system. The location of that directory is defined in the file `C:\dazzler\data\params.txt`. One should find here a line of the form :

```
D  <param_folder_nickname>  <Parameters Directory Path>
```

The location of the parameter folder can be changed : see subsection 5.5.2 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
```

Comments start with the exclamation mark "!". However, files which are `rw`[6] 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.

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

[6] ie. read/write

Lowjitter, *sequence* and most options implemented.

This file is created by FASTLITE and should never be changed. Otherwise, the generator and software might stop working completely.

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 *Trig&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.

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 check boxes, knobs and controls (see chapter 6).

If the waveform was programmed using[7] the files "`AMP.txt`" or "`PHASE.TXT`", the contents of these two files are stored in "`wave.txt`" in sections `#AMP` and/or `#PHASE`. 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 combinations between multiple buffers. Each of them is saved and restored when reading the wave file (section name: #mem0).

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**.

Other Files

Some other files may be found among other parameter files. They can be divided into three different types:

- calibration files,
- files for Dazzler™ system options,
- copies of the last used configuration.

Files for Dazzler™ system options

Data files that are required for some of the Dazzler™ options. They are read and written by the application program.

```
rw  lowjitter.txt  data for Low jitter option
rw  cepcalib.txt   calibration data for CEP option
```

[7] when either the control `Amplitude` or `Phase` having value file(1) or both(2)

Copies of the last used configuration.

These files are copies of the last version of some of the parameter folder main files. They are only written by the application program before exit.

```
wo  DazCurrent.old  copy of the previous version of the DazCurrent.txt file
wo  DazMain.old     copy of the previous version of the DazMain.txt file
```

Be Careful that only the last used configuration is copied. These files cannot be used directly to re-initialize the parameter folder. It is **strongly advised to store a copy of the delivered parameter folder before** using the Dazzler^{TM} system, and to store a copy after each successful setup[8]. In case you didn't store the original set and require it, please contact FASTLITE . We will send you a copy of the parameters folder **as when delivered. All the adjustments made during the installation setup need to be re-done...** Good practise is to include the parameter folder in the regular backup scheme.

5.5.2 Location of parameters files

One may have to define explicitly the location of the parameter folder to the software, especially after a reinstallation on another computer.

On a working installation, one can change the parameters set by using the "Change Set of Params" button in the `Monitor -> maintenance` window.

If the program fails at startup due to a wrong parameters set path, it is possible to reset this setting :

1. make a copy of the file (if it exists) `C:\dazzler\data\params.txt`,
2. delete the file,
3. restart the software. The window shown in Figure 5.13 should appear.

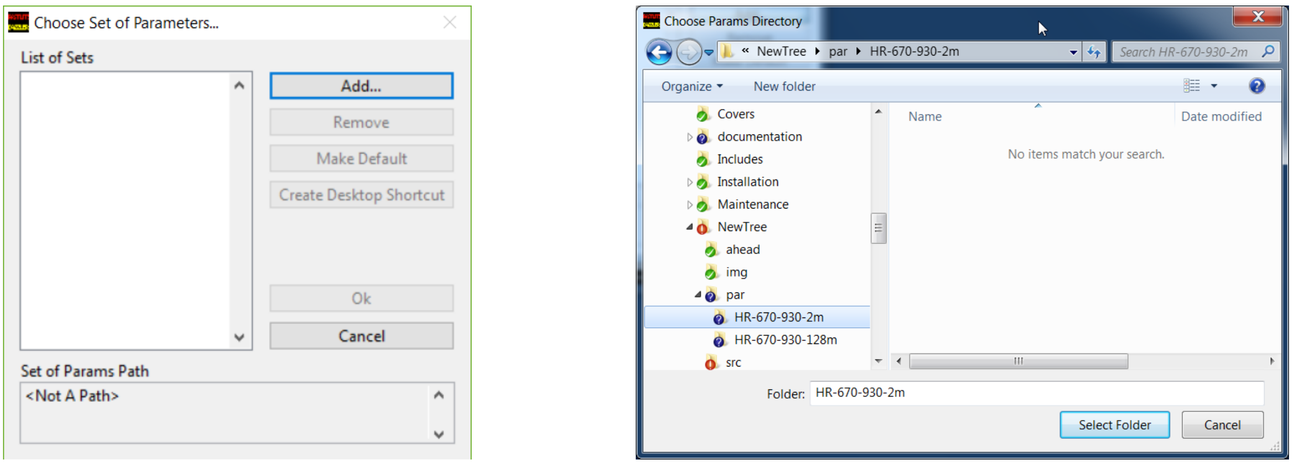


Figure 5.13: Selection of Parameters Directory

[8]Every time a significant change is done in *Trig&Mode* settings, in the low jitter settings, ...

Choose "Add...", and browse the filesystem to find the directory containing the parameter folder. When "inside"the parameter folder, choose "Select Folder". The basename of the selected directory should appear in the "List of Sets". When this name is selected (highlighted), its absolute path should appear in the box "Set of Params Path"[9].

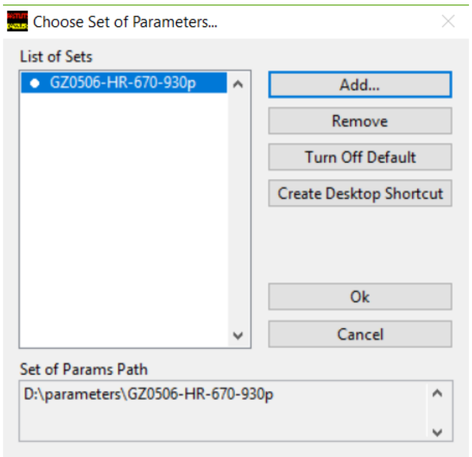


Figure 5.14: Default parameter set selection

To allow the software to start automatically using one set of parameters, one should click once on "Make Default" when the required set is selected. This will put a white dot at the left of the line. When the window looks like on left just click "OK". The software should then start normally using the selected parameters.

5.6 Alarms operation

Alarms have been implemented to protect the Dazzler™ and the laser system in which it is installed.

- the conditions which may raise alarms are checked regularly, polling rate above 10Hz,
- the presence of an alarm is indicated by the "poll message" (see software front panel) which becomes red and bold, as shown below, and the L2 indicator blinks red,
- alarm conditions are "sticky": this means the alarm needs to occur only once to be remembered until it is cleared by an explicit operator "acknowledgement". Thus a temporary fault will raise an alarm condition which will last until it has been "acknowledged" by the operator. Alarm acknowledgment requires opening then closing the *monitor configuration* panel. **Note that issuing this command stops the RF generation**.

  The message after the f/limit value depends on the alarm type (see section subsection 5.6.1 for more details).
- an alarm condition makes the L2 LED blink rapidly (Figure 5.17).
- a description is given in the alarm box of the Monitor Configuration panel as shown below.

[9] the operations which can be done are self explanatory, they will be described in another version of this manual

Figure 5.15: poll message : no alarm

Figure 5.16: poll message : alarm(s) present

The message depends on the alarm type (see section 5.6.1 for more details).

- these alarms do not interfere with the RF generation: it is up to the operator to decide when to switch off.

Please keep in mind that these alarms have been implemented to protect the generator, and thus, it is strongly recommended to stop the generator and contact FASTLITE **in case these faults are continuously detected**.

5.6.1 Alarms description

The alarms presently available are:

- the speed of any fan is too low. Depending of the system, there can be one to five[10] cooling fans. The alarm text attempts to identify the faulty fan,
- the RF amplifier temperature is too high[11].

Exhaust fan speed

The exhaust fan is very important for cooling the generator. It is located on the generator rear panel. Its nominal speed is $\approx 3900rpm$. The speed is based on the measure of the fan rotation sensor period. An alarm is raised when the speed is below 50% of the nominal speed which is shown right between () in the *monitor config* panel. On the software front panel, the poll message indicates that the fan alarm has been raised as shown below.

[10] normally there are 2 fans: cabinet exhaust and RF amplifier. High power amplifiers, when not water cooled, have 4 to 5 fans

[11] most RF amplifiers have a thermoswitch in the amplifier enclosure which trip if the output transistors temperature goes above 70^o

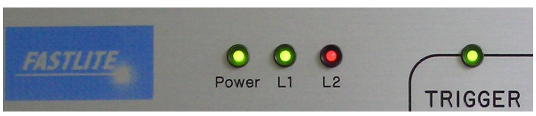


Figure 5.17: L2 indicator blinking : alarm(s) present

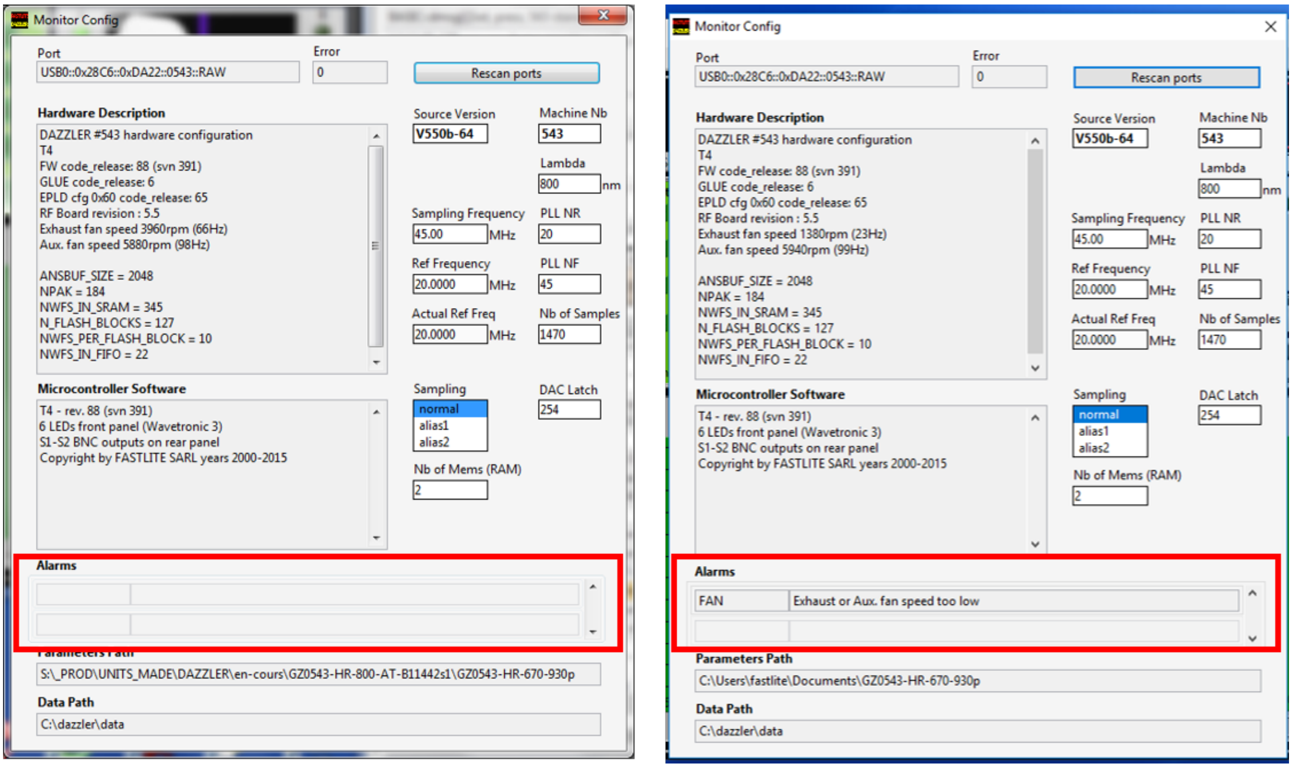


Figure 5.18: poll message : no alarm

Note that the *monitor configuration* shows the current fan speed, hence a speed alarm could have been raised when the speed was abnormal but is now back to normal, as shown on Figure 5.19.

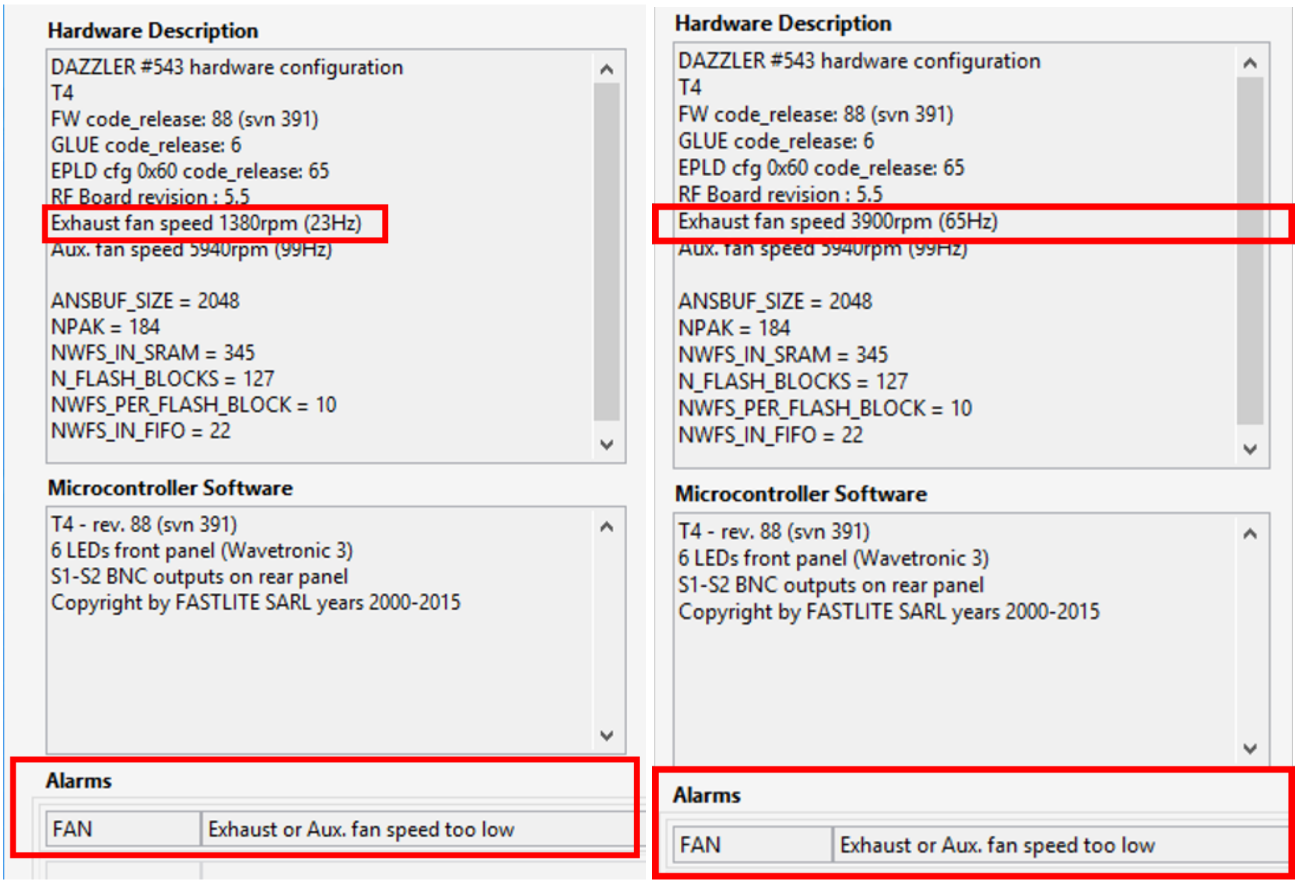


Figure 5.19: Exhaust fan alarm present

Curative actions:

Immediate: switch off the generator as soon as feasible. Do not operate with this fault.

Long term: liaise with FASTLITE for a replacement unit.

Aux fan speed

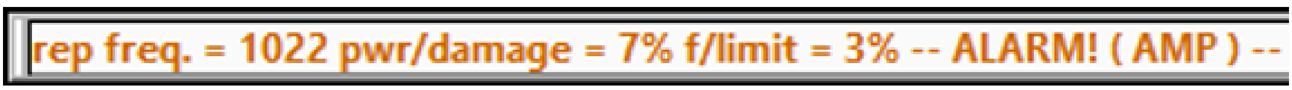
The Aux fan is the fan within the RF amplifier module. It is located behind the generator front panel. Its nominal speed is $\approx 5900 rpm$. An alarm is raised when the speed is below 50% of nominal. In this case, the message *"FAN: Exhaust or Aux. fan speed too low"* appears in the alarm box of the monitor configuration panel as for the exhaust fan alarm. On the software front panel, the poll message indicates that the fan alarm has been raised.

Curative actions:

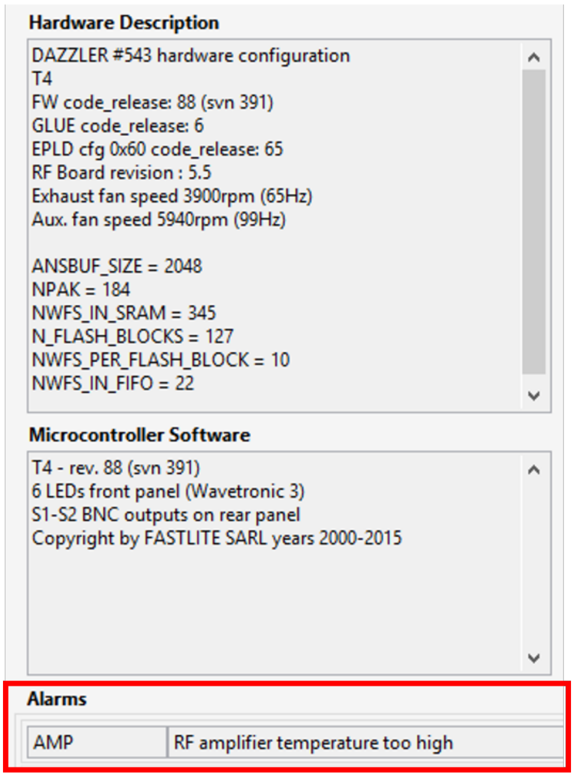
Immediate: switch off the generator as soon as feasible. Do not operate with this fault.

Long term: liaise with FASTLITE for a replacement unit.

RF Amplifier temperature



The RF amplifier temqperature is not measured but a thermal cutout switch raises the alarm when the output transistors reach 70^{o}degC. In the alarm box of the Monitor Configuration panel, a message appears as shown at right. On the software front panel, the poll message indicates that the amplifier temperature alarm has been raised as shown below.



Curative actions:

Immediate: switch off the generator as soon as feasible.

Long term: investigate cooling conditions and liaise with FASTLITE . Things to investigate: 1) obstructions in front of the air inlet & outlet openings, 2) generator positionned on a hot surface, 3) not enough "breathing space" at the rear exhaust fan...

When two alarms are raised, a message specific to each alarm appears in the alarm box of the Monitor Configuration panel. On the software front panel, the poll message indicates the presence of several alarms. Closing the monitor configuration panel acknowledges all the alarms shown.

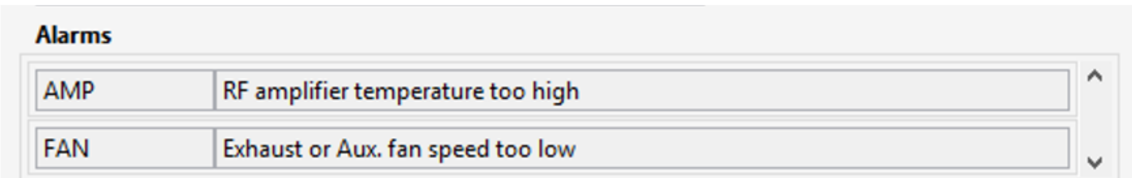


Figure 5.20: Monitor Configuration panel : several alarms

Figure 5.21: poll message : several alarms present

5.7 Warnings

Two other conditions cause the "poll message" to become red and bold, as shown further. Contrarily to alarms, these warnings do not signal impending damage to the Dazzler™system but that conditions are not correct (e.g. missed triggers due to delay). They disappear when the cause is removed: there is no storage of temporary conditions nor any acknowledgment.

5.7.1 Missed triggers due to timing

Figure 5.22: missed triggers due to timing

This warning appears when triggers are ignored because they occur 1) during the delay period, 2) during the copy operation between different memories (sequences, aux selection ...), 3) delayed triggers during gate. This warning is disabled for generators operating in the High Repetition Rate mode (see section 4.3.5).

5.7.2 Missed triggers due to power

Figure 5.23: missed triggers due to power

This warning occurs when the average power to be delivered to the crystal would exceed the crystal damage threshold. The Dazzler program prevents such a situation to happen by preventing loading or switching waveforms as appropriate. This may happen after a waveform is loaded and the trigger frequency is increased. In order to protect the crystal, triggers are ignored during a protection period, computed to limit the average power.

5.7.3 Missed triggers unreported

The Dazzler RF Generator is used to generate an analog signal which is sent to the crystal transducer to generate the appropriate acoustic pulse. This signal is generated by a Digital-to-Analog (DAC) converter, which takes its input data from a dedicated memory buffer. When one needs to update the shaping parameters of the Dazzler, the content of this buffer must be overwritten. While the buffer content is being updated, it cannot send any data to the DAC, hence the RF generation is stopped temporarily. If a trigger occurs during the time window when the buffer content is being modified, the trigger is ignored, without any notification to the control computer.

This generally occurs each time the user applies new shaping parameters to the Dazzler, including when (but not limited to) :

- a new waveform is loaded into the memory currently-in-use:
  1. selector "Loading In..." set on `"A"` (blue area), while the upper right selector (in machine controls) is set on `"A: Mem 0"`. This selector in machine controls is called the display selector.
  2. selector "Loading In..." set on `"B"` (blue area), while the display selector is set on `"B: Mem 1"`.
- the display selector position is changed between `"A: Mem 0"`, `"B: Mem 1"` or `"A/B: Alternate"`. Any change in the display selector causes a memory (RAM) to memory (display) transfer.
- when applying a logic one signal (section 8.3) to the AUX input while the display selector is set on `"B"` : the AUX signal is specifically used in this case to force the generator to display `"A"`.

The duration of the buffer load operation is proportional to the waveform size and the basic clock period. Using the HR example shown in Figure 5.11 to obtain the actual waveform size, one only requires the number of packets $NPAK$.

$NPAK = 184$. It takes $3 \times 12.5ns$ to transfer one byte from RAM memory to the display memory buffer, and $33 \times 37.5ns = 1.24\mu s$ to transfer a packet (1 header byte + 32 byte data) from RAM to display buffer, a single waveform transfer lasts $NPAK \times 1.24 = 228\mu s$. This gives a global value, the actual hardware and firmware may differ. When the display mode is Alternate, two waveforms are required.

5.8 Troubleshooting

5.8.1 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 described 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.

5.8.2 E-mail reports

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

AU CHOIX ... ou un mlange!? Citations du courrier SAV:

Please use the address *sav@fastlite.com* fork your queries: it automatically reaches several people in Fastlite so that the first of us who is available will answer as soon as possible.

Using this address instead of the address of a person will ensure that your request will be handled even if your usual correspondany is absent.

For support, it is recommended to use the "*sav@fastlite.com* address, *info@fastlite.com* havinga different purpose, being used mainly for commercial inquiries.

We cannot help you without the serial number of the generator, found on the back panel for older units and on the front panel for recent systems.

5.8.3 Screen captures

To help us understanding your problem please send us a copy of your parameters directory (see subsubsection 5.5.1) along with as much screenshots as possible. At the minimum, copies of the main window and of the `Monitor->Configuration` will be greatly appreciated.

Parameters set should put in a ZIP archive, while the screen dumps should be stored as PNG, as this format uses 20 times less space than the default Windows BMP[12].

Checklist for submitting problems

- ☐ the serial number of the generator ____________
- ☐ the parameters set folder (one ZIP file)
- ☐ screen capture of monitor → configuration (PNG format)
- ☐ screen capture of main GUI window (PNG format)

[12]Irfanview is free software is useful to perform screen captures using little space and conversions between image formats. It can be obtained at: `https://www.irfanview.com/main_download_engl.htm`

CHAPTER 6

Remote control

This chapter introduces the protocols, control commands and available functions to control the Dazzler system from an program exernal to the Dazzler process.

6.1 Remote control generalities

6.1.1 Client-Server models

The Dazzler program can be viewed as a server providing the services of the Dazzler system[1]. Most of the operations that can be performed from the front panel can be driven remotely, while the main Dazzler program is running.

There are three ways to communicate with the Dazzler program, namely:

1. by a human operator "manually" setting control values and pushing buttons using the GUI[2],
2. with an "'ad-hoc" IPC[3] by text commands called "text file" mode. In this "text file" mode, the Dazzler program acts like a spooler operating on text files: this is slow but very general. The "text file" mode interface is based on text files generated by the remote user program. This mechanism has some advantages:
   - the remote user program can be written in any programming environment or language, e.g. LabView, Visual Basic, C, Python, etc.
   - the remote "requester" program does not need to run on the Dazzler computer: it is sufficient to share the 'default directory' (see subsection 5.3.1) via the network and to give write access to the requestor.
3. with a fast socket method based on the LabView™ socket implemention. It is introduced briefly in this chapter and has an on-line documentation CHM file.

[1]computation, signal generation and driving the Dazzler crystal.

[2]GUI: Graphic User Interface

[3]IPC: Inter Process Communication

6.1.2 Documentation

Both remote access methods are supported by LabView libraries. During the Dazzler program installation, the libraries are bundled with the Examples, hence make sure this feature is installed. There are two help files (LabView like) `DzNetRem_Help.chm` for the socket based library and `DzTxtRem_Help.chm` for the "text file mode". They document completely the functions (Vi's) available, and the example utility programs provide the necessary documentation to get further.

For other languages than LabView, documentation support is limited. Examples coded in Python and using DOS batch script may be obtained on request. They only document the "text file" protocol.

The path to these examples is given by the icon "Vxyz-Examples", most often:

```
C:\Program Files\Dazzler\V550d - Examples\Source Code
```

Note that the socket based IPC uses some of the formats developed for the text file IPC, thus reading once all the sections is advised since an attempt to avoid duplication was made.

6.2 Basic text remote control

This mode of operation is activated by setting/toggling the *remote enable* menu option in the *Setup* menu (the unit accepts remote commands but can still be operated manually). The "remote enabled indicator" lights up on the front panel. When the main Dazzler program is running in this mode, it periodically checks for the existence of a text file named `request.txt` in the default directory (see subsection 5.3.1). The active indicator blinks for a short time whenever such a file is found. In the simpler case, the file contains a single line of text describing an absolute path to a wave text file, see Figure 6.1.

The file associated with this path is read. The front panel controls are modified according to its content. The new time signal is computed and is transferred to the Dazzler RF Generator.

The effect is thus identical to a manual change of the controls, followed by a single push on the load button. When the controls have been set and associated actions have been performed the file `request.txt` is deleted. The remote "requestor" program can thus wait for the request file to disappear to determine that the remote actions have terminated, and proceed with the next operations.

6.2.1 Requests

Requests are text files named `request.txt` put in the default directory (see subsection 5.3.1). This name is hard coded and cannot be changed.

In the `request.txt` file, the first line is generally a wave file path, which format follows section 5.4. The parameters in the wave file describe shaping changes to be applied on GUI controls. These changes can be performed even if the generator is "offline", which can be useful to simulate wave shapes.

The wave file path may be followed by a list of "star" commands to be performed *before* the processing of GUI controls. These lines follow the format: `*Command [value]`. The main purpose of these "star" commands is to operate the buttons and other controls which are not accessible by the controls allowed in wave text files. These commands are described in subsection 6.2.5.

A summary of the request files required is shown next on Figure 6.1.

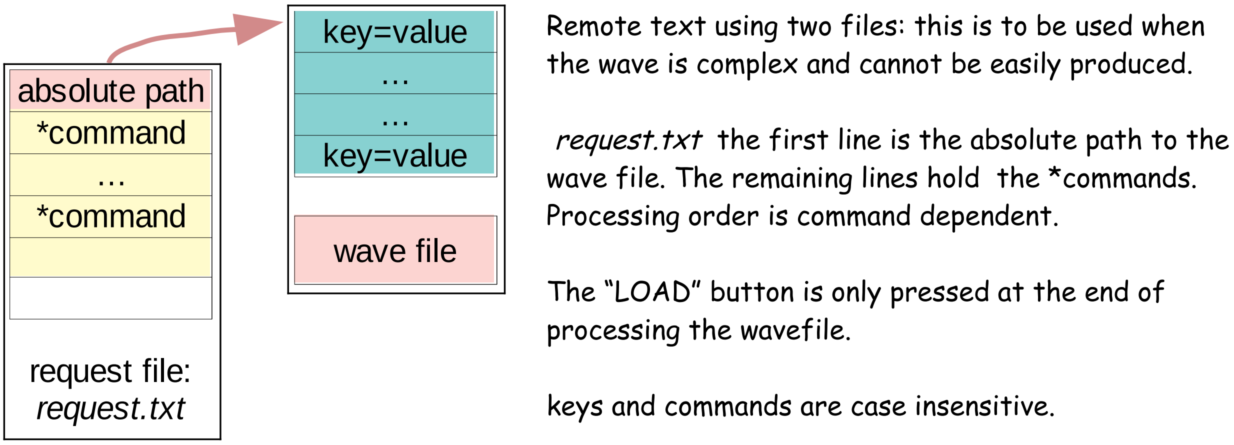


Figure 6.1: Remote text using two files

Processing of the request file information is as follows:

1. star commands **first**
2. wave file controls including amp & phase section,
3. waveform loading.

If preferred, it is possible to include the wave file directly in the request file, as described in subsection 6.2.6.

6.2.2 Atomic write

This IPC, based on a protocol of reading/writing a file in a shared folder [4], requires that the operations, 'create', 'write' and 'close' necessary to post the request file `request.txt`, be uninterrupted ("atomic"). If not, it may occur that the polling Dazzler program will access the request after creation but before its complete writing thus resulting in an unreliable mess.

Examples of reliable code to write request files and testing for request file deletion are shown in the VI `PerformRemoteCall.vi` of the library `DazzRemoteControl.lvlib`. It was found

[4] Inter Process Communication

that the "rename" operation is atomic (ie. unbreakable) across local area networks. The implementation to post a request is thus done in two steps:

1. write a temporary file `request.tmp`. It does not matter if this write operation is interrupted.
2. atomic operation: `rename-file request.tmp request.txt`.

The above also implies the underlying assumption that a single requestor process is active with a given Dazzler.

6.2.3 Error handling

Please note that there is no "error" or "completion code" returned to the program having issued the request. The GUI will post appropriate error reports in dialog windows expecting an operator to be present. The activity will resume once the error is acknowledged unless the remote requester "times out"[5]. This unfriendly behavior is corrected in the network remote protocol, instead of the "fire and forget" behaviour of the "text file mode", there is return information from the Dazzler.

When a new waveform need be sent to the Dazzler, the user program can either generate a new `request.txt` with a path to another wave text file, or modify the wave text file and issue again the same `request.txt` file. The adequate wave text file can either be generated from the Dazzler program using the *save as* menu option or directly written by the user remote control program.

6.2.4 File C:/dazzler/paths.txt

The file `c:\data\paths.txt` is a leftover (relict) from early use of the Dazzler in network configurations. This file is now only an indicator for two paths used by the last Dazzler GUI having changed its remote enable status. The first two records are set to the 'default directory' , the third indicates the parameters path: **essential for bug reports !**. This file resides in `c:\dazzler`. Having a single location prevents to use it in two dazzler installations.

6.2.5 Star commands

In the `request.txt` file, the wave path may be followed by a list of "star" commands to be performed *before* the processing of GUI controls. These lines follow the format: `*Command [value]`. The main purpose of these "star" commands is to operate the buttons and other controls which are not accessible by the controls allowed in wave text files. The commands themselves are not case sensitive[6].

[5] It is not easy to investigate a fault when `request.txt` has just been deleted! The trick is to disable remote from the GUI: then `request.txt` will remain.

[6] but for boolean values where lower case 't' is the only way to obtain a True value for *CONT...

The "star" commands currently implemented and disclosed are listed next. Some depend of the generator being "on line", but most often, simulating a waveform is possible without perturbation to the signal generation[7]. Note that the order of execution of the star commands may be important[8]: the only guaranteed method to impose the order of execution is to issue requests having a single command or control.

In the following:

- [HW] means hardware "on-line" required for correct execution
- **b** boolean: entering "t" produces a True value, "f" or "0" yield False. Note that the only way to enter a true value is with lower "t".
- **n** integer

CONT b Enables/disables the continuous mode [HW] .

CYCLING b When True, "Alternate" becomes "Cycling".

MEMA n Changes the memory slot pointed by A. Error window if **n** is beyond the generator limit or if the memory **n** is not present. Dazzler generators have various amount of memory, this is indicated by the "Nb of Mems (RAM)" box on *monitor* ⇒ *configuration* panel [HW]'.

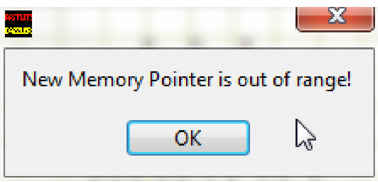


Figure 6.2: Out of range memory pointer

MEMB n Changes the memory slot pointed by B [HW].

ONLINE b Operates the on/off line status [HW].

ONLYCOMPUTE b Does not load waveform, just computes it and write results into `c:/dazzler/data/SpectraCurves.txt` [9]. This command can be used to check if a waveform is safe to load in the crystal. This command issues a fake "LOAD" and does not affect the hardware.

REM_LOAD_EN b Operates the remote control status. Note that once set to OFF (F) the `request.txt` file is no longer being polled, hence the transition remote-off to remote-on can only be achieved by the manual action of the operator or by the socket interface.

[7] typically, one would display memA and load in memB
[8] for waveform combinations
[9] 4 columns: col0=lambda, col1=amplitude black curve, col2=lambda, col3=amplitude red curve

SAVE_WAVETXT path Saves, in the **absolute** path, a wave file, containing the parameters of the front panel of the last computed waveform. The waveform saved corresponds to the current state of the controls, it is the last action performed of a request. BEWARE: a relative path will crash the Dazzler program (behaviour present in V560b).

SWB n The value of *Save to data buffer* (in the combination area) is set to n, then the save button is "pressed".

WAV n The current display mode of the generator is modified:

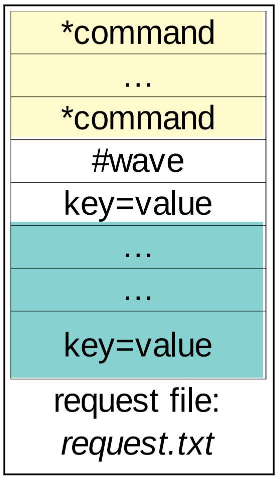
n=0 → mem.A, n=1 → mem.B, n=2 → alternate A/B.

A & B are not symmetrical: when B or A/B are selected, (aux) may force a switch to A.

6.2.6 Wave file inclusion in request (#wave)

The remote protocol has been simplified to operate with a single request file holding all the information, so that an additional wavefile is not required. This uses a line equal to "`#wave`" **after** the star commands from the wave information. When such `#wave` keyword is found, all the remaining of the request file is considered to be the content of the wave file, potentially including `#amp` and `#phase` subsections (see section 5.4).

The use of the `#wave` keyword is mutually exclusive with the specification of a wave file path as first line of the request. If both are included, behavior is unpredictable and unsupported.



Remote text protocol using a single file: *request.txt* which combines setting the *commands and some of the controls found in a wave file. The control lines typically modify a few variables after initial loading of a more complex wave file. The controls are separated by the line #wave.

The *commands are partially processed first, followed by the wave controls. Processing order is command & control dependent. To force processing order: submit separate requests.

The "LOAD" button is only "pressed" at the end.

Figure 6.3: Remote text using one file

6.3 Dazzler Network Remote Toolkit

6.3.1 Scope and Principle

In addition of the “text file” remote protocol described earlier, FASTLITE provides another way to control the Dazzler^{TM} remotely, through a network connection. The main advantage of this new protocol resides in the fact it avoids the use of files, which is time consuming. This protocol is thus much faster.

The Dazzler^{TM} GUI being programmed in LabVIEW, the protocol used is based on a proprietary protocol from National Instrument which allows the remote execution of VIs in a distant application. Thus, the toolkit allowing the remote control of the Dazzler^{TM} is provided as a LabVIEW library, called the “`Dazzler Network Remote Toolkit`”.

To remotely control the Dazzler^{TM} through this toolkit, a program must follows the following steps :

1. Initialization, which opens a communication channel with the Dazzler^{TM} and prepares for execution the different functions that will be remotely called.
2. Use the different functions provided to perform the necessary actions on the Dazzler^{TM}. The description of these functions is delivered as a CHM (LabVIEW typical help file) included with the library. The functions descriptions can be directly obtained through the “help” feature within LabVIEW, just like any other integrated VI.
3. Before terminating, a “CLOSE” function must be called so that the connection with the Dazzler be closed and the library internally saved data be freed.

6.3.2 Walk through of a simple code

To introduce remote control based on the `Dazzler Network Remote Toolkit`, follow the commented ”walk through” next. Figure 6.4 shows the diagram (code) of a basic included example called `DzNetRem_EmulateTxtRemote.vi`.

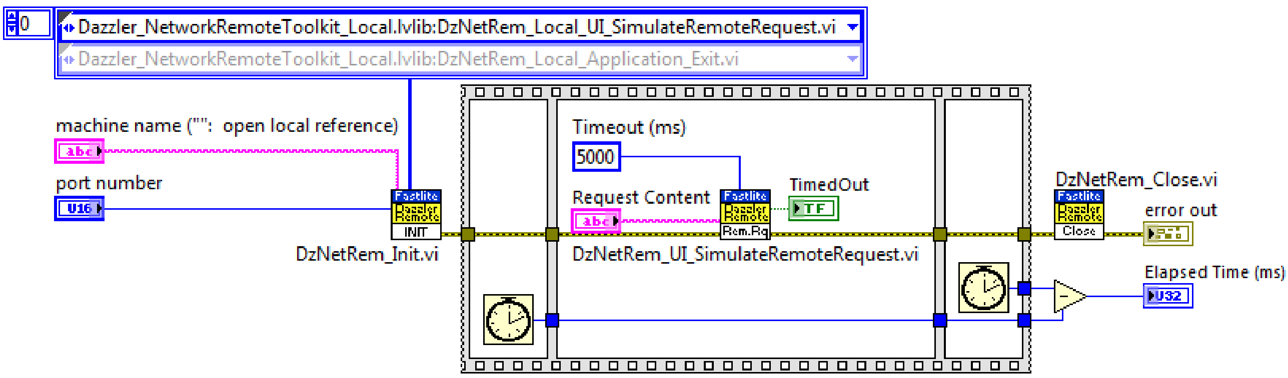


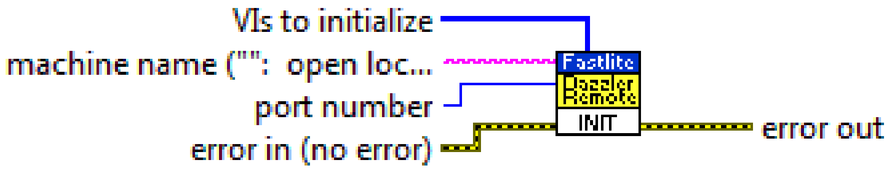
Figure 6.4: `DzNetRem_EmulateTxtRemote.vi` diagram

LabView execution model is to follow all the signal paths until held up by not yet evaluated data. A node present in a block diagram will execute only when data is present at all of its inputs. After the execution of a node the output data of the node is transmitted to the next node of the dataflow path. The execution order of the VIs and function on the block diagram is determined by the movement of data through the nodes. Typically, chaining of the error signal (error_in, error_out) defines the order of execution. For signals equivalent in terms of evaluation, the actual order of evaluation is left to the compiler.

This example demonstrates the compatibility layer with the legacy "text file" remote protocol described in section 6.2. It basically implements the steps described above : init, call remote function, close. In addition, timing of the complete transaction is conducted: note the use of the "flat sequence" to enforce execution order. The timer readings are done in "separate frames".

The requestor program opens the communication with the Dazzler™ by calling the `open.Vi`

INIT
`open.vi`

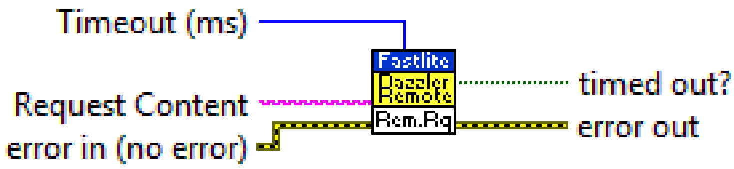


The arguments are the host IP address[10], the port number is defined in the Dazzler INI file, in the same way as the 'default directory' (see subsection 5.3.1). The connection is kept open by the library until the call of `close.vi` (see below).

The input parameter "VIs to initialize" is supposed to provide the list of the remote functions that will be called by the remote program. This is mainly for performance purposes. If not connected, the library will prepare itself for the execution of every remote function provided in the toolkit, which takes a lot of time[11].

The example program next shows the use of the remote funtion which emulates the text file mode. It does the same things as with files, without actually writing any file to pass information, which makes it a lot faster.

REQU
`dorequest.vi`



This VI sends the "Request Contents" string, without any checking, to the Dazzler program. The syntax is the same as that of a `request.txt` file as described in section 6.2. To be totally freed of the use of files, it is recommended to use the `#wave` keyword in this request to directly include the content of the wave parameters, as described in subsection 6.2.6.

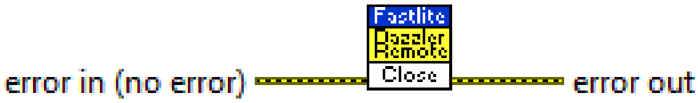
The constant "Timeout(ms)" is the time allowed to wait for an acknowledgment from the Dazzler program. Its default value of 5 seconds is adequate for most cases.

[10]for local traffic on the same computer is standardised to `localhost`, with IP address `127.0.0.1` while on the network the machine has a proper IP address

[11]Measured improvement: from 260ms "unwired" down to 35ms "wired" references.

CLOSE

`close.vi`



The `close.vi` must then be called before the client program stops. This closes the network connection with the Dazzler software. Failure to close properly will consume resources, slow down and eventually crash the programs involved, including the Dazzler[12]

[12]Not releasing resources often causes memory leaks.

CHAPTER 7

Cabling tips

The laboratories where the Dazzler^{TM} systems are used are often full of noisy signals which may impair the proper operation of the system. This chapter provides tips on the layout of the cables. These tips are also applicable to other equipment, like pockels cells, trigger generator, etc. and have to be applied to the whole platform to control the interferences.

7.1 Basic principles

Reduce area between ground plane and cables.

Do that for both the noise producer and the sensitive piece of equipement. This will reduce harmful emission from the noise source and reduce the received perturbations.

Typically, the noise sources are pockels cells high voltages switches. Victims are USB cables, attached PC and Dazzler components. Trigger cables and trigger box, if low jitter is required, are also affected.

7.1.1 Ground plane, layout & crossings

The top of the optical table (the mechanical reference) should be connected to earth for safety. For EMI/EMC control this is not effective and the following tips may/have to be implemented. The first step is to turn the mechanical reference into a good RF ground plane (RF electrical reference). If the sheet is made of aluminum alloy, the surface may be not conductive due to the aluminum oxide. Check this with an impedance meter. If made of two or more sheets, these sheets shall be bonded together with copper or aluminum conductive tape[1]. The cables have to be laid down to the ground plane or as close as possible to the conducting surface.

When a power cable has to cross a signal cable, it should do so at right angles and be kept as far as possible from the signal cable.

This layout minimizes the coupling[2] between the cables. If you are using pockels cells with a

[1] Ex: French Radiospares, Advance Tapes, AT 526 Conductive Copper Tape, 10MMX33M,Ref.: 542-5505.

[2] Mutual inductance

fast high voltage switch or any fast high power equipment, these parts (may) create a lot of EMI perturbation. They have to be properly shielded, usually they are in metallic housing and you have to ground them, through their conductive baseplate, or with adhesive copper tape, or heavy copper braids.

All coaxial cables shall have their BNC or SMB plug externally grounded, either through the receiving plug/box or with extra copper tape.

7.1.2 Use of EMI ferrites

Protecting the electronics from noise can also be done by inserting ferrite beads right at the input sockets. Snap-on modules[3] can be used, such as shown on Figure 7.1.

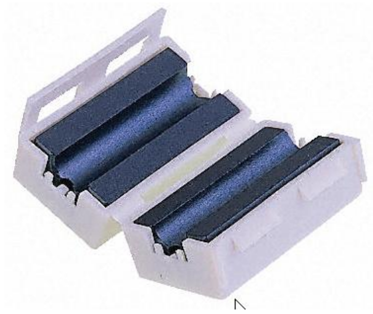


Figure 7.1: Snap-on EMI ferrite

7.1.3 Termination of signals

High speed logic signals must be properly terminated to avoid reflections. The input signals to the Dazzler should come from 50Ω sources via 50Ω cables and be terminated properly with a 50Ω load.

It is often necessary to insert a Tee to observe a signal. To minimize the impedance mis-match, the impedance of the input fed by the Tee should be high, while the signal is terminated at the end. Thus the impedance of the Dazzler inputs TRIGGER and AUX is kept high, so as to feed an oscilloscope input which has an internal 50Ω termination. Do not use a Tee positioned at the source, this will lead to reflections. Figure 7.2 shows three correct wirings.

7.2 USB cable

If the USB cable "sees" too much noise, the communication between laptop and RF generator will stop erratically[4], thus leading the software to declare the unit "off-line": use the shortest possible cable, with proper layout and ferrites on both ends.

[3] Exemples of such modules: french RS 116-1471, uk RS 222-4343

[4] On T1 interfaces the loss of communication due to improper cabling layout accounted for a significant number of service calls we received ! The T4 interface is more robust.

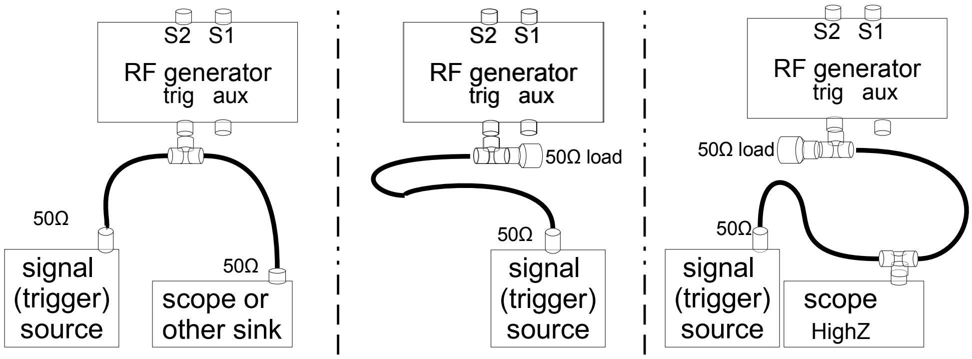
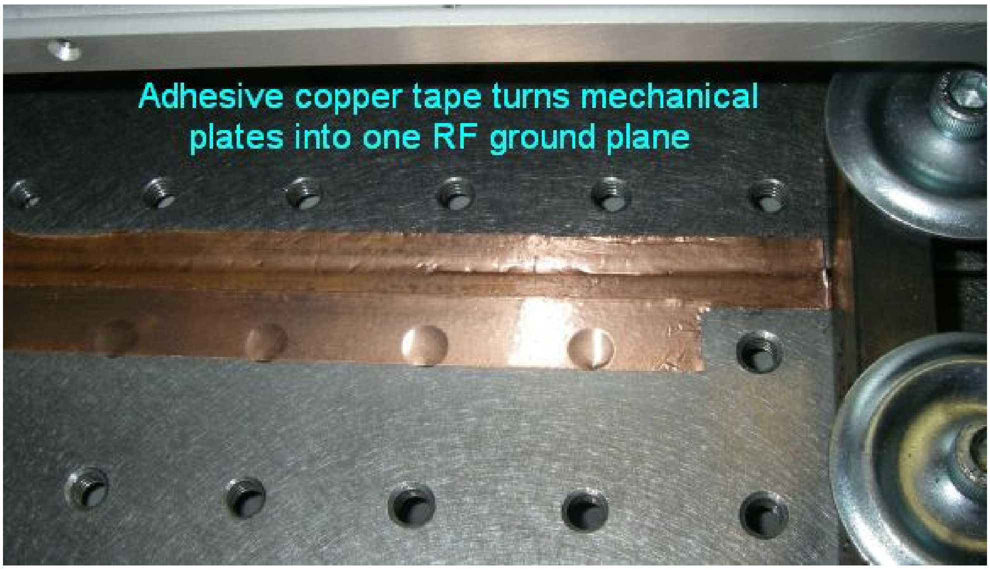


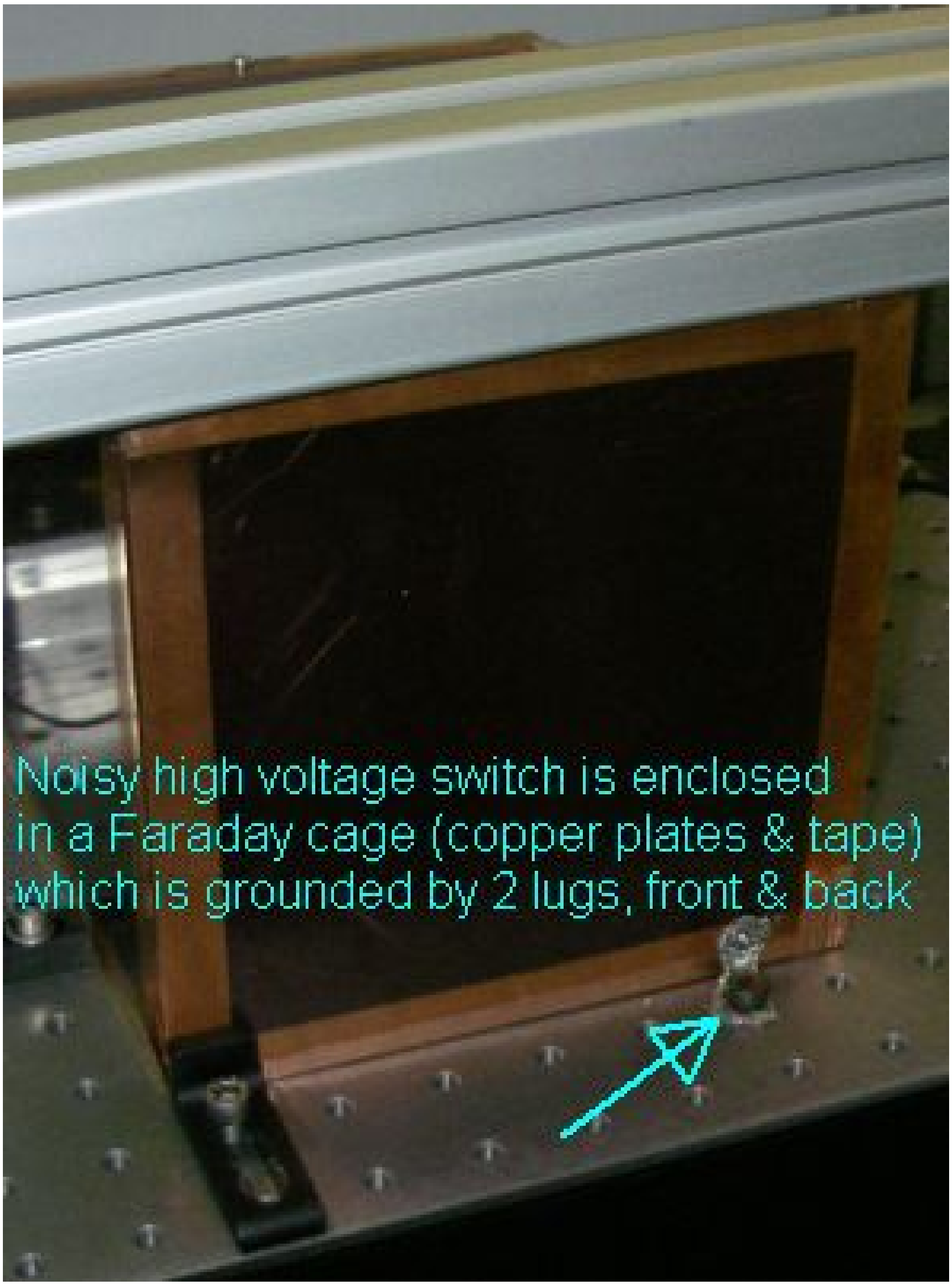
Figure 7.2: Correct TRIGGER wirings

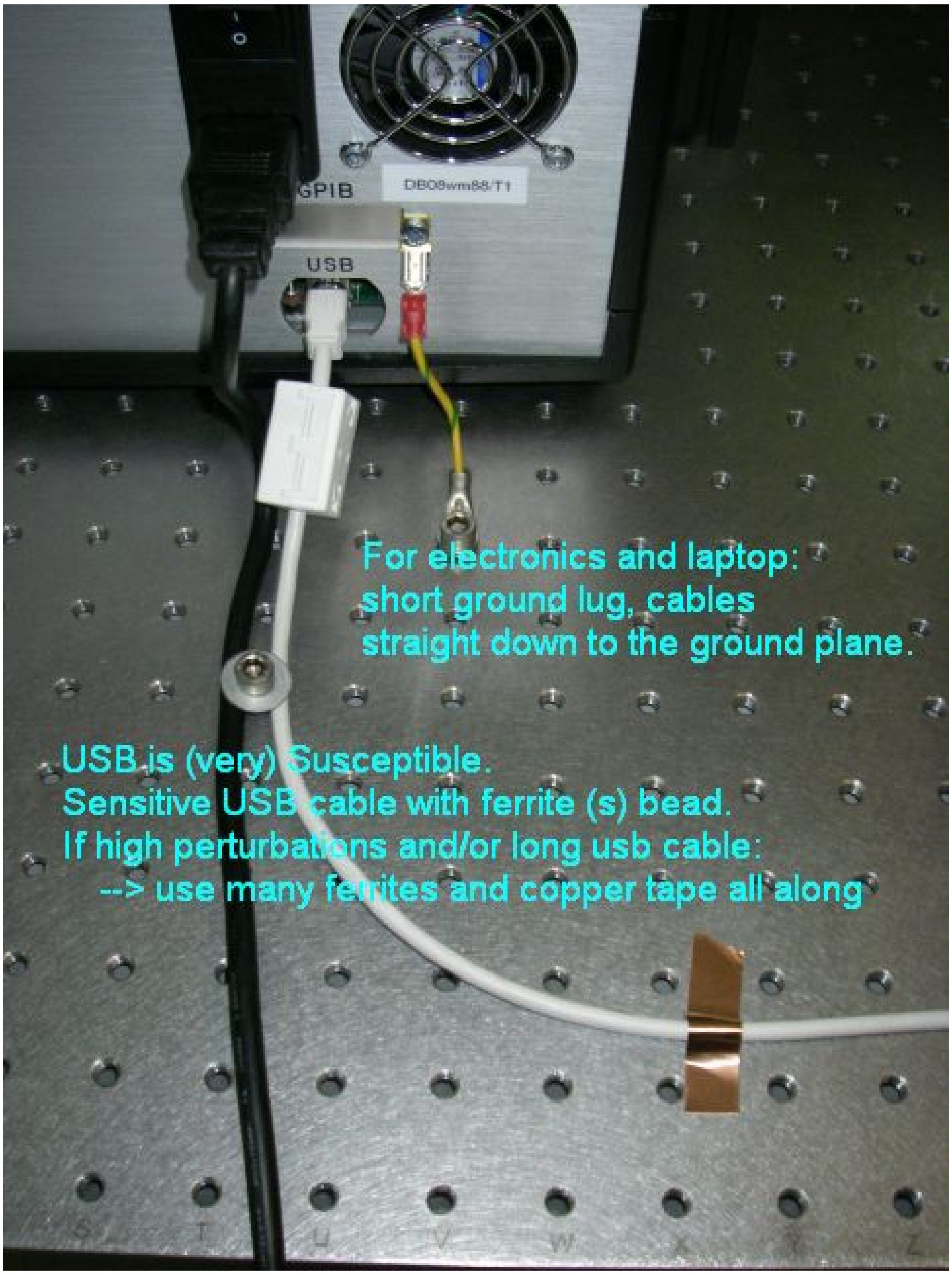
7.3 Practical examples


Adhesive copper tape turns mechanical
plates into one RF ground plane


FASTLITE
DAZZLER
RF & Trigger cables
straight down to the ground plane
+ ferrite bead(s)


Check that plates surfaces are
conductive (not hard anodized)
TENMA
72-7750
0.7


Noisy high voltage switch is enclosed
in a Faraday cage (copper plates & tape)
which is grounded by 2 lugs, front & back


GPIB
DB08wm88/T1
USB
For electronics and laptop:
short ground lug, cables
straight down to the ground plane.
USB is (very) Susceptible.
Sensitive USB cable with ferrite (s) bead.
If high perturbations and/or long usb cable:
--> use many ferrites and copper tape all along

CHAPTER 8

RF Generator description

8.1 Overview

The RF generator is the electronic unit which translates the signal definitions in the computer into the electrical signal[1] applied to the crystal and the ancillary logic signals interfacing with the laser system.

The RF signal repeats periodically when the unit is programmed in the "continuous" mode and is generated only once for each trigger signal in the "single" mode, see section 8.6 for timing diagrams.

On the front panel are found the inputs TRIGGER and AUX controlling the generation process.

BNC outputs **S1, S2, S3** and **S4** on the rear panel are used for driving data acquisition & control equipment and for monitoring signals with an oscilloscope for troubleshooting.

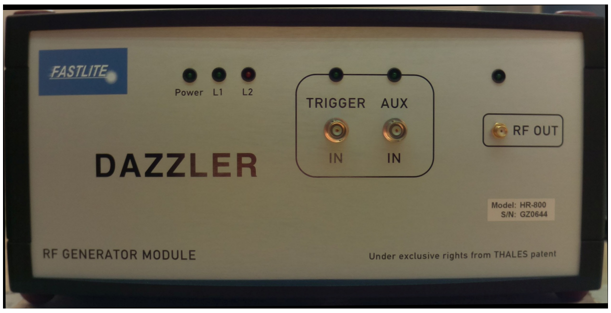
Figure 1.1 shows a simplified schematic of the RF generator.

8.2 Indicators

This sub-section describes the RF generator front panel LED indicators.

There are 6 LED indicators on the RF generator front panel: Power, L_1, L_2, TRIGGER, AUX and RF_ON (above RF OUT output power SMA plug).

[1]uniformly sampled arbitrary waveform



Note that the indicators are verified at each power_up sequence: the indicators should blink 3 times slowly.

8.2.1 Power indicator

The *Power* indicator monitors the 5V internal power supply and should be steady. If unlit, check that the mains cord is correctly plugged to a live mains plug, check on the rear panel that the fuses[2] are not blown: the power supply may be "damaged".

8.2.2 L1 indicator

The *L*1 indicator is used to show the actual state of the microprocessor. In normal operation, the LED is blinking at 1 Hz. It stops blinking if the microprocessor crashes. In this case, restart the RF generator. Before switching off, if possible, **zero** the displayed waveform as required by some RF amplifiers.

8.2.3 L2 indicator

The red *L*2 indicator signals alarm conditions: it blinks rapidly when an alarm condition has been detected (see section 5.19). The normal condition is off or "unlit".

8.2.4 Trigger indicator

This is the LED just above the TRIGGER_IN BNC input socket. This indicator will lit when the trigger rate is measured *after the generator goes succesfully online*. It blinks at the trigger rate under 100Hz and is steady above[3].

8.2.5 AUX indicator

This indicator, just above the AUX BNC plug, unlike TRIGGER is not driven by a retriggerable monostable circuit but by the buffered AUX signal. It is unlit when the AUX socket is empty,

[2] with mains in the range 210V-240V use 2A slow blow when replacing
[3] the LED is driven by a retriggerable monostable multivibrator 74xx123 set at 10ms

or when the AUX signal is LOW. The indicator follows the signal at the AUX input.

8.2.6 RF_ON indicator

This is the rightmost LED, just above the RF output power SMA plug. This indicator is lit when the RF generator board sees a non zero signal being output in the RF cycle. This is not an indication of power, it just means RF cycles are produced with non zero samples.

8.3 Logic levels & signals

The logic signals of the RF generator are interfaced with special cable drivers integrated circuits[4]. Logic levels are TTL: LOW is below 0.6 V, HI is above 3.3 V. Refer to the datasheets for more details. Some newer generators equipped with RF boards V5.6 are fitted with an internal jumper selecting between 5V TTL and 3.3V TTL.

High speed logic signals must be properly terminated: see subsection 4.1.1 for the TRIGGER and AUX signals Dazzler input. chapter 7 is full of practical advice to avoid unstabilities due to EMI.

8.4 Input signals

8.4.1 Input signal TRIGGER

This signal is essential to the successful operation of the Dazzler with the laser system. Please refer to chapter 4 for more details. The following actions are started by the TRIGGER:

- the rising edge of the TRIGGER pulse starts a retriggerable multivibratorTRIGINA, subsequent rising edges occuring while TRIGINAis high are blocked but restart a blocking period (only for TRIGGER pulses applied to the BNC socket).
- the rising edge of TRIGINA starts the delay period,
- the internal delayed trigger GENTRIG starts the RF cycle, it is blocked if falling in the protection period PROTECTP. The protection period is defined by the waveform being displayed. It prevents to start another waveform if the average thermal power delivered to the crystal would exceed the safe limit.
- note that TRIGINA comes from an unsampled analog circuit.

[4]The following chips have been used: 74AC14B, 74LVC14D, 74AHC1G14, 74AC14D.

8.4.2 Input signal AUX

In standard Dazzler configurations, AUX is used for various synchronization schemes. This signal is a level sampled at the trigger rate. It forces the selection of waveform A when B is displayed in normal, alternate and wave cycling modes.

8.4.3 ExtClock

The Low Jitter hardware option brings a major change in the operation of the Dazzler RF unit: the reference clock for the generator of the sampling clock[5] is fed from the oscillator train. This allows to synchronize the complete system to exhibit jitters below 300ps.

8.5 Output signal RF out

RF out: this is the SMA terminal which provides RF power to the crystal module. It should be properly connected to a 50 Ω load or to the crystal, failure to provide a load may damage the RF generator.

The nominal output is 10 W, translating to 60 V peak-to-peak. This signal should not be connected directly to an oscilloscope, but via a 40 dB power attenuator, otherwise the oscilloscope is likely to be permanently damaged. This point is **very important**, as many calibration procedures imply to connect an oscilloscope on this signal. The power attenuator should be capable of withstanding 20 W or more.

The frequency band depends upon the generator model. The table below shows the cutoff frequencies in MHz. Cutoff is very sharp, as it is numerically generated.

model	Fmin MHz	Fmax MHz	Fdata MHz
HR800	71.7	103.8	45.0
HR1053	57.6	70.9	33.0
LN-1030	305.7	326.3	
LN-1500	160.1	243.8	
LN-1700-2700	106.1	181.3	96.0
UWB-650-1100	36.8	66.8	46.0
WB800	43.7	62.2	27.5

Table 8.1: Typical frequency bands

[5] its multiple and sub-multiple

item	value		meaning
TXtal	32.66	μs	duration of acoustic interaction
Fdata	45	MHz	sampling frequency
Fc	85.93	MHz	RF or acoustic frequency at 800 nm
GENDEL	1.45	μs	generation delay

Table 8.2: RF cycle parameters for model HR25-800

8.6 RF cycles description

The oscillograms shown are based on a standard HR25-800 Dazzler crystal, Table 8.2 gives the necessary parameters to define the wave generation.

8.6.1 Single cycles

This is the normal mode of operation where one RF cycle is started by an external TRIGGER . Refer to the Figure 8.1 next.

- the bottom yellow trace (C1 scope channel) shows the attenuated RF output.
- the blue trace (C3 channel) shows TRIGINA which is the reshaped trigger pulse[6]
- the red trace (C2) displays GATE which is the logic signal indicating that the RF generation is active[7]. GATE occurs after a programmable delay, here set at about $30\mu s$.
- the green trace (C4) shows the PROTECTP signal, see Figure 8.7.4.
- Figure 8.2 shows similar conditions but for the time scale and green trace showing `highwhenA`. The RF signal (yellow trace) is slightly late with respect to GATE. The delay between the rising edge of TRIGGER and the start of RF generation depends of the sampling frequency (Fdata) and varies from 300ns to $2.3\mu s$. This delay is called GENDEL.
- Figure 8.3 has similar conditions as in Figure 8.1, except that the trigger mode has been changed to NO DELAY mode: notice the small delay between TRIGGER and TRIGINA,
- on Figure 8.3 between TRIGINA and GATE and between GATE and the start of the RF signal. The delays depend of the sampling period $1/Fdata$.
- these delays are "lumped" in the T_{prog} control found in the *Trig&Mode* panel. Originally, T_{prog} meant the propagation time between the transducer face and the optical face where the acoustic wave is reflected. It now includes all the irreducible delays.

[6]The TRIGGER pulse applied to the BNC goes through a Schmitt trigger and a retriggerable monostable. The blocking period is set with a jumper 10 μs or 0.5 μs used in the RF board circuits. Any value in that range can be obtained by changing a special jumper.

[7]Due to the pipelined DAC with digital filtering, the actual RF signal is 48 samples late at the output. This delay is significant but is only one contribution to T_{prog} ..

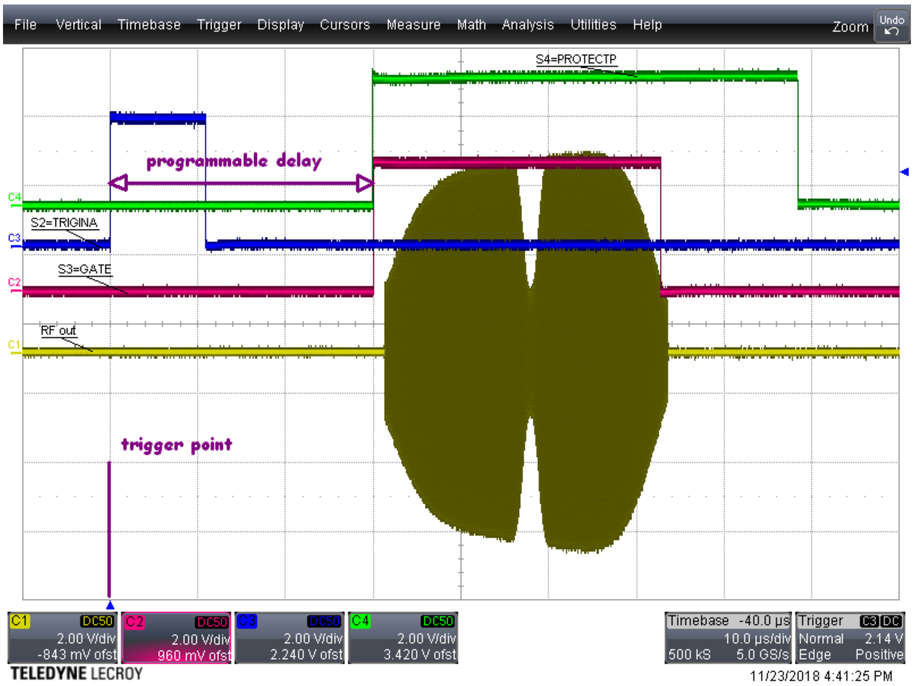


Figure 8.1: RF cycle programmable delay

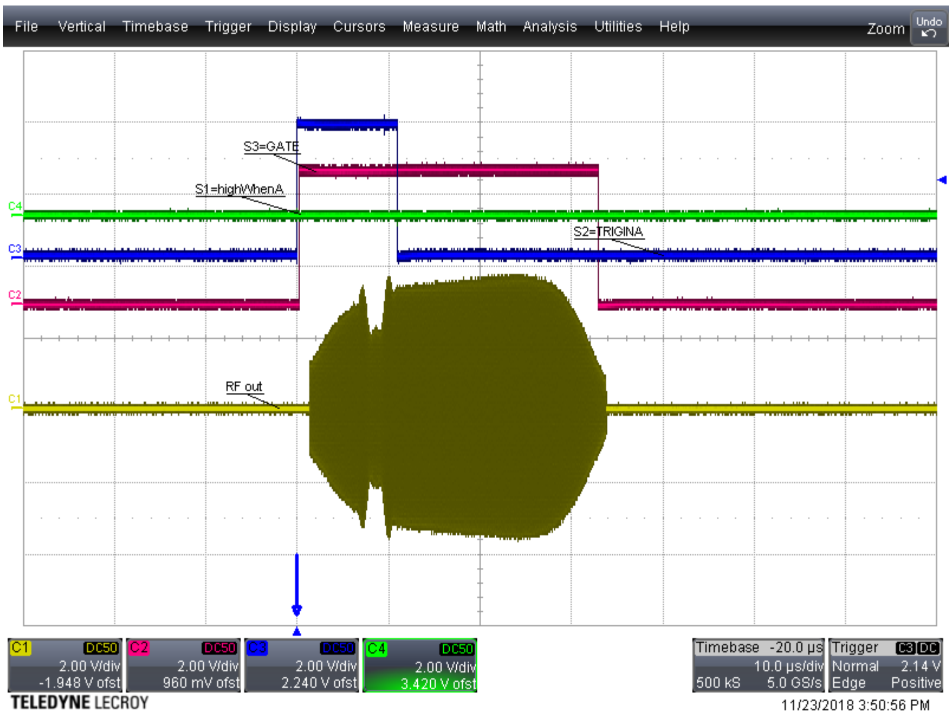


Figure 8.2: RF cycle no delay

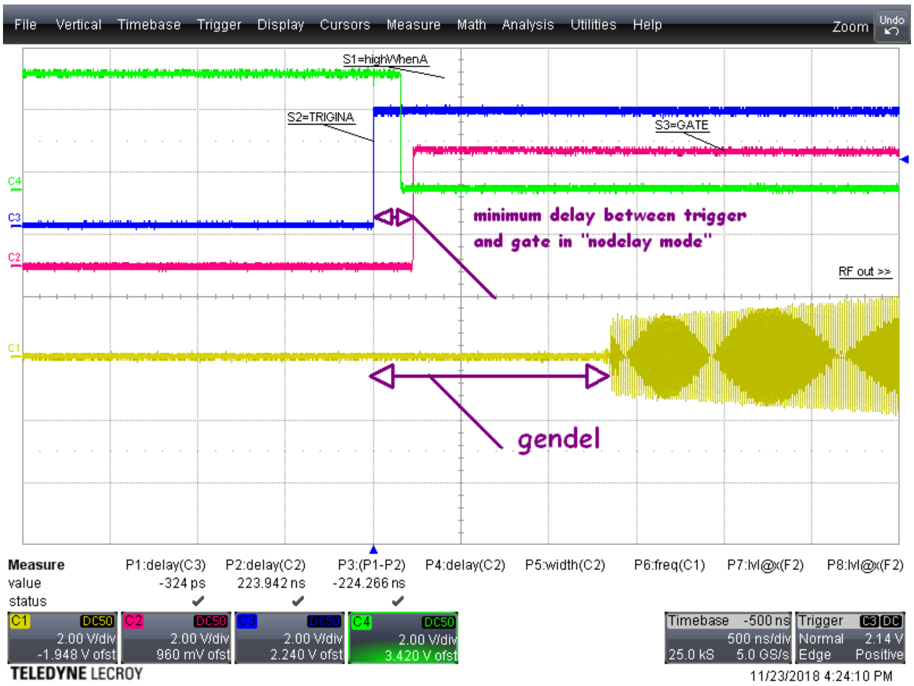


Figure 8.3: Standard RF cycle - no delay - zoom

8.6.2 Continuous mode

This mode is reserved for low power and alignment. It deposits a lot more power into the crystal. As soon as a cycle is finished, another one is started: this is done during several sampling clock periods. The external trigger is only used to re-synchronize[8]. See Figure 8.4. Truncation of one waveform cannot be avoided on every trigger, unless the trigger period is an integer multiple of GATE duration + a few 100 ns.

8.6.3 Alternate mode

On Figure 8.5 the blue vertical arrow at the frame bottom is the scope trigger point. The red trace is GATE. Memory A is loaded with a wide waveform with one trough and memory B has 3 peaks.

The next oscillogram on Figure 8.6 shows when both continuous mode & alternate are selected. The red trace shows GATE while HIWHENA is shown on the green trace. This demonstrates the alternation of A & B and that the signal HIWHENA can be used to synchronize external equipment[9]. HIWHENA changes state on the trailing edge (at the end) of GATE. This gives enough time to the synchronised equipment to switch as well as removing ambiguity on the waveform displayed. Note that TRIGPARITY is similar to HIWHENA and is always pulsing, even when there is no change is selection A or B.

[8]the trigger used to be required to start generation but an internal change in the firmware starts generation when the mode is asserted, thus the trigger is only used to re-synchronize. Some customers run their Dazzler WITHOUT any TRIGGER connected !

[9]typically used with a lockin amplifier

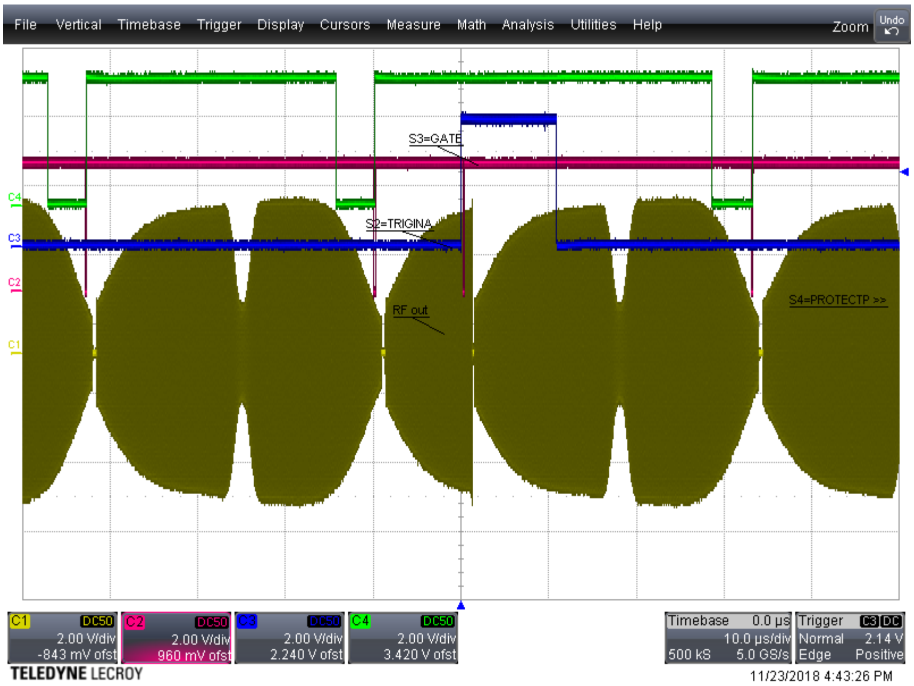


Figure 8.4: Continuous mode

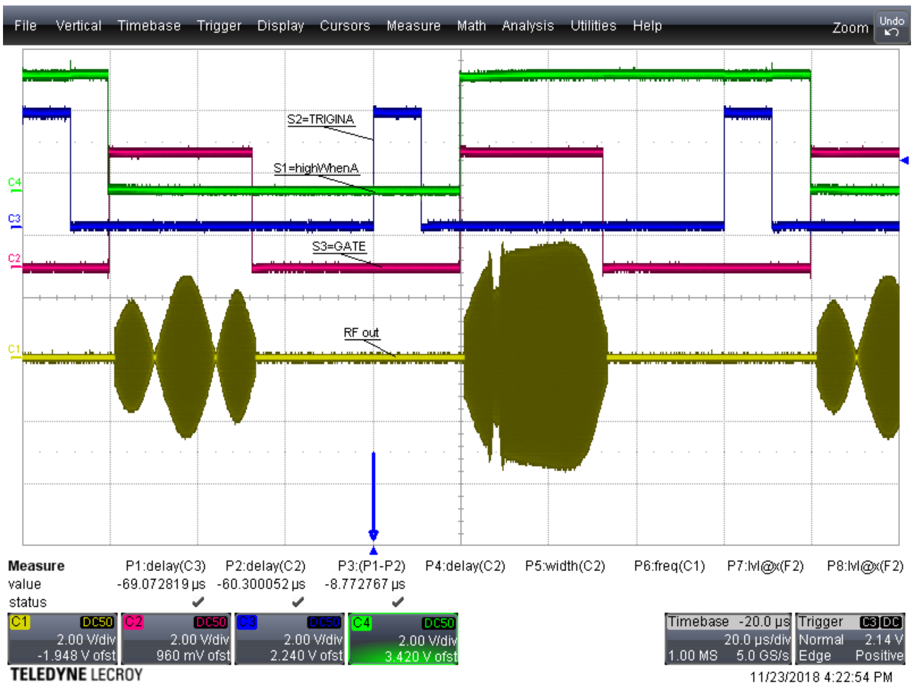


Figure 8.5: Alternate mode

When both alternate and continuous are selected, generators with RF boards 5.x show the pair of waveforms AB repeated continuously. Earlier generators repeated the same waveform between triggers: many A and on trigger many B instead of many AB.

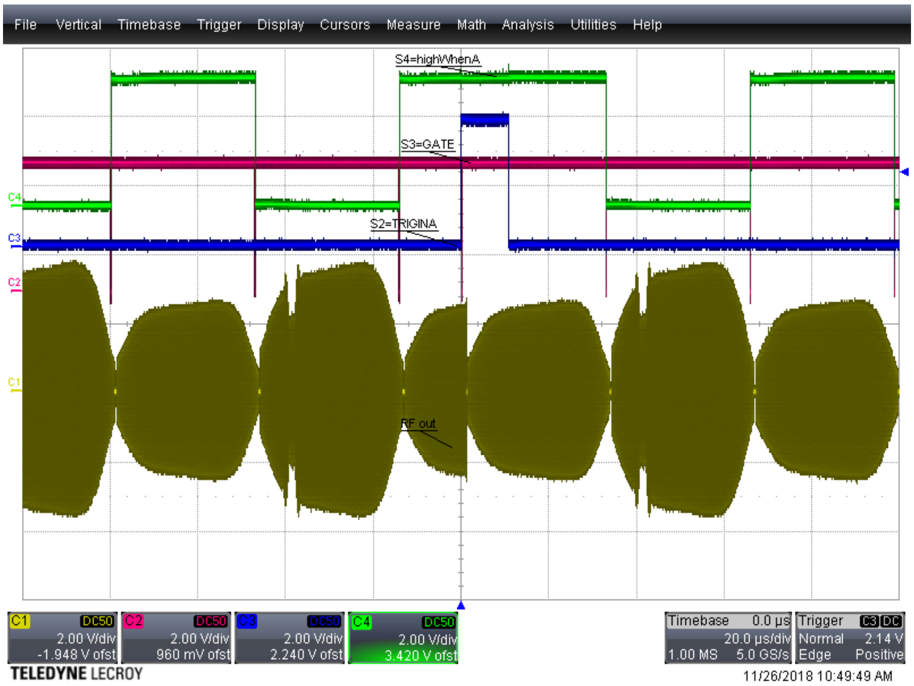


Figure 8.6: Alternate & Continuous mode

Details & Warnings:

- logic low selects waveform B, while logic high selects waveform A. If the BNC AUX is unconnected, the signal is low,
- the AUXCOPY available on S1 eases debugging
- AUX is sampled at the trailing edge of GATE. A memory transfer from SRAM to FIFO is initiated whenever a change in AUX is detected. Using memory SRAM:

  $TransferTime = (T\_xtalxFdata)x(3/80E6)x(33/32)$

  if $TriggerPeriod < TransferTime$ there will””missed triggers”

It is also used to synchronize the sequences in burst mode.

8.7 Output signals S1-S4

These signals are defined by the hardware options purchased as well as the firmware loaded in the generator. The signals available on your Dazzler™ system and their output assignment are shown and selected by the software *Trig&Mode* panel. The list of available signals is revealed by a click on the scroll control of each output.

8.7.1 Output signal S1

Back panel BNC S1: output of a TTL logic signal which is related to the operation of the generator, the actual signal to be chosen via a selector with 8 choices, see further. Affectation of the signals depends of the firmware of the RF board. Changes are required at each generation of RF boards, the actual lists can be seen in the selectors appearing in the *Trig&Mode* panel.

8.7.2 Output signal S2

Back panel BNC S2: output, in particular used to generate a self trigger signal: the selection T1OUT is forced in internal triggering mode, total of 8 choices, see the implemented signals by opening the *Trig&Mode* panel.

8.7.3 Output signal list

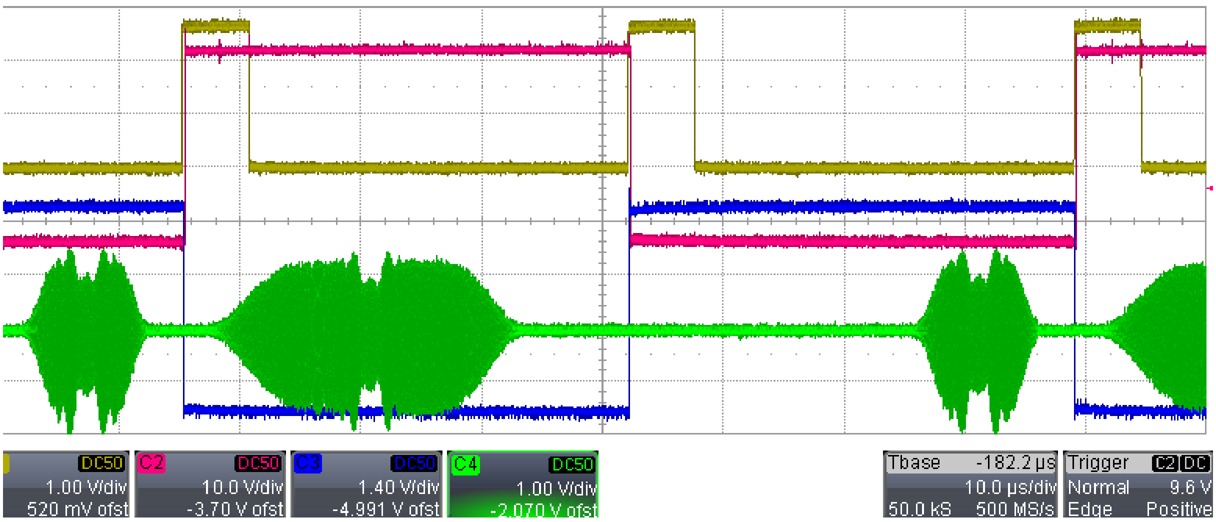
extracted from Siegman/PROD/.../DAZZLER/GZ0655.txt	
signal	usage RF board V5.x
(CHOP and FIFOGATE)	triggers/N in streaming sequence
(GATE and (/CHOP))	pulsed triggers (N-1)/N
(GATE and CHOP)	pulsed triggers 1/N
/(CHOP)	inverted triggers/N
/GATE	OFF during RF signal
/GATEBASIG	inverted gating signal (option g)
ALTDELSRC	alternate delay indicator
AUXCOPY	aux input copy
BOARDBUSY	memory access
CHOP	triggers/N
FIFOCMDSTATE.0	FIFO Transfer Idle
FIFOREP	FIFO repetition overflow
FSMPCNT.4	fdata/32
FSMPCNT.5	fdata/64
FSMPDIV4	data sampling clock, divided by 4
GATE	ON during RF signal

extracted from Siegman/PROD/.../DAZZLER/GZ0655.txt	
signal	usage RF board V5.x
GATEBASIG	gating signal (option gating)
GENTRIG	read trigger
GND	LO level
HIWHENA	hi when wave A is played
HWABUSY	hwa.busy (option hwa)
HWASTROBE	hwa strobe (option hwa)
MISSTRIG	Trigger rate too fast(FIFO load)
PROTECTP	protection period
QCLK	quartz clock
S1SEQSYNC	sequence synch (option seq)
S2SEQSYNC	sequence synch (option seq)
SEQPARITY	sequence: wavenumber is even (option seq)
T1OUT	generate internal trigger
TPARITY	trigger parity =ie.trigger/2 (reset by S7)
TRIGINA	trigger block
VCC	HI level

8.7.4 Descriptions of selectable signals

- `hiwhenA` "high when wave A is played" is useful in alternate mode, or when waveform B is selected and a high level is applied to the AUX terminal. Logic level LO corresponds to waveform B, logic HI corresponds to waveform A. The TPARITY choice is based on the triggers processed and not on the waveform selection.

  traces: red = HIWHENA, yellow = TRIGGER , green = RF, blue = TPARITY



- GATE "ON during RF signal" the GATE signal is at high when the RF signal is generated: it comes HI on the delayed trigger and goes to LO after the RF cycle has completed. It comes slightly earlier than the RF signal[10]. /GATE is negated GATE.

[10]the generation delay varies with the sampling frequency.

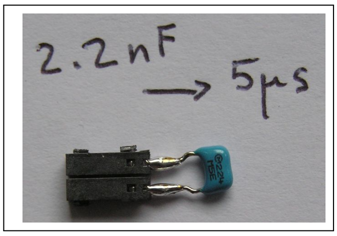
- GENTRIG "read trigger" a short pulse which triggers the RF cycle (ie "gate" signal) if the conditions allow it (power ok, protection period elapsed, ...). This pulse is useful to debug lost triggers. The width of this pulse is the sampling period, ie. in the range 5-50 ns.

- FSMPDIV4 "data sampling clock, divided by 4" can be used to synchronize external equipment or to verify that the sampling clock is as expected (PLL locked in low jitter systems). Older generators output the sampling clock. Slower signals fsmpcnt(4-5) are available on S3-S4 for debugging.

- S1SEQSYNC AND S2SEQSYNC "sequence sync selection" reserved for synchronization in sequence mode.

- AUXCOPY "aux input copy" logical copy of the aux signal: used to verify operation of AUX.

- TRIGINA "trigger blocking" All external triggers received during TRIGINA are inhibited. Note that each trigger occuring within TRIGINA restart the monostable for a period and thus lengthen the signal. This is wanted to filter out rebounds, but will fail to recognize any trigger if the frequency is above 1/TRIGINA.



It is possible to adjust this blocking time between 0.5μs and 10μs by using a jumper equipped with a capacitor. Removing the jumper is necessary to operate at 100kHz.

C2 nF	t μs
10.00	8.2
2.20	5.0
1.50	4.1
1.00	3.1
0.68	2.4
1 0.47	1.8

- CHOP is a signal which can be used to perform an operation every N triggers. N can be adjusted from 2 to 254 (default to 10 at power up). Use to be described in an "separate" note.

blue trace = TRIGINA, red trace = GATE, green trace = /(CHOP)

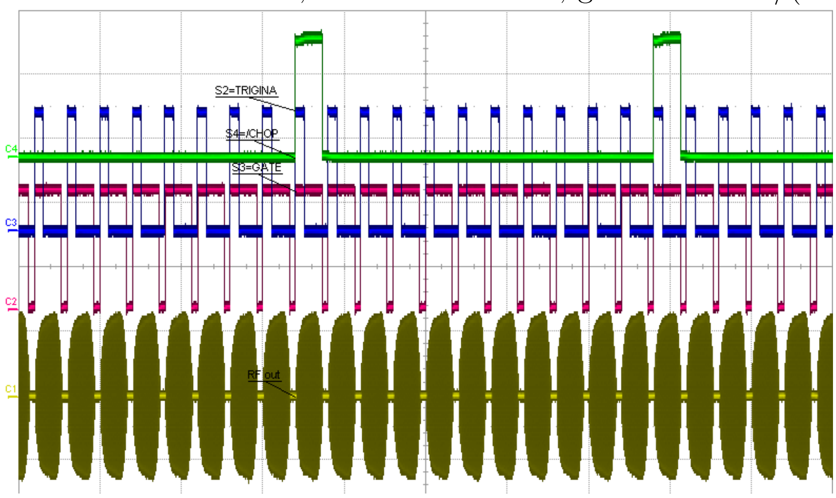


Figure 8.7: Generation of a logic high every CHOP cycles

- PROTECTP = "protection period", triggers are disabled during this time, so as to protect the crystal from thermal damage. The following pictures show increasing power, the red trace is PROTECTP, the green trace is the RF signal and GATE is on the blue trace.

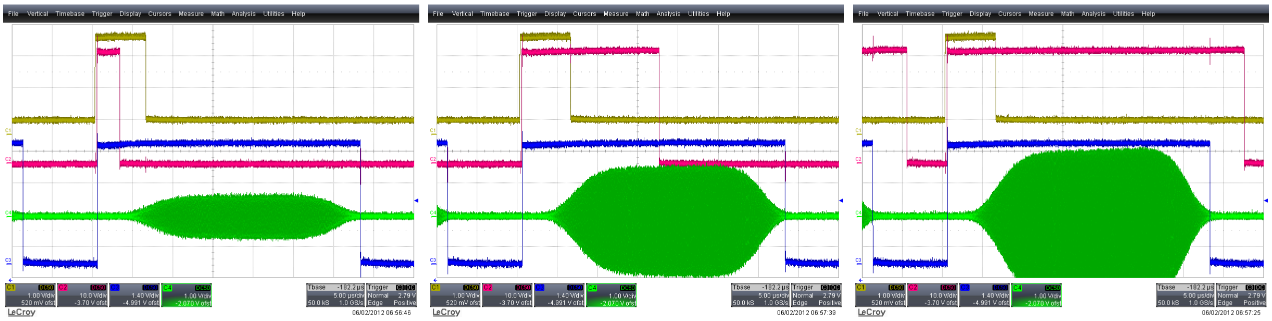
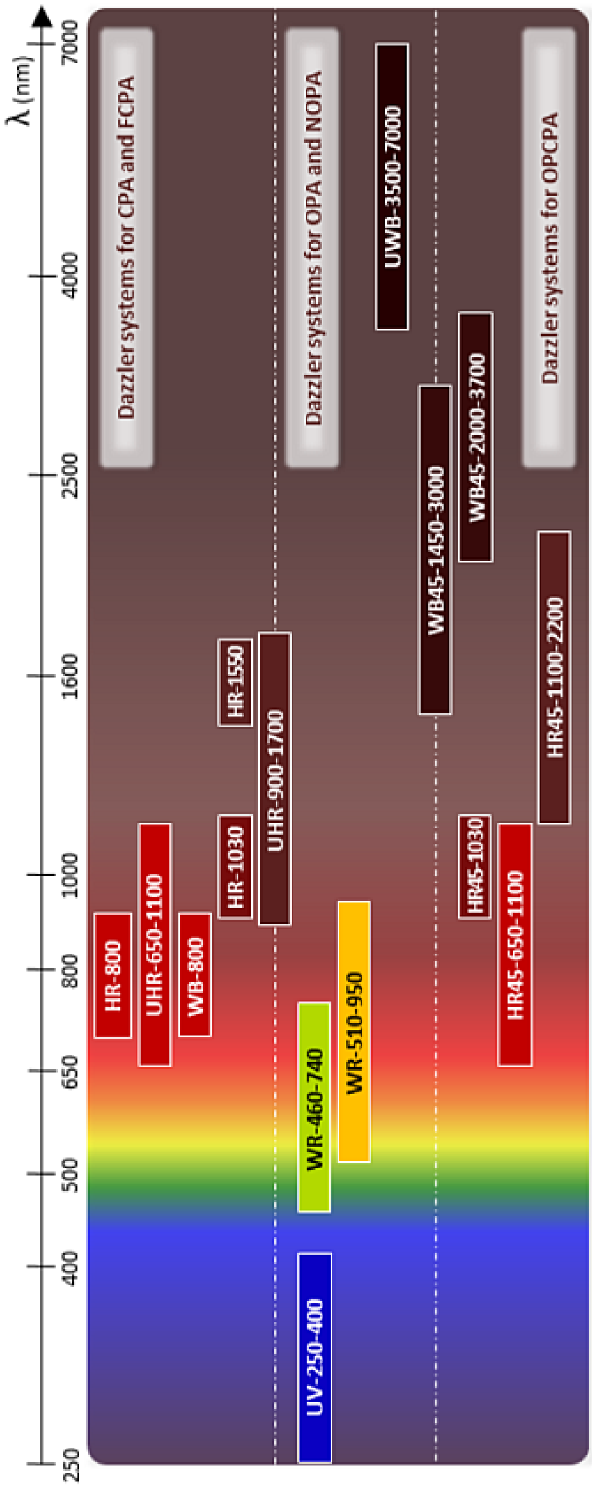


Figure 8.8: prevent thermal damage by disabling triggers during PROTECTP

- GND - VCC or logic values LO - HI: these levels are used to verify the operation or cabling. In Mazzler mode, S2 is used to control a shutter. Beware that these levels are NOT guaranteed to be steady. During the operation of the Dazzler program, they may be pulsing. They are steady if the Dazzler^{TM}program is only polling.
- fsmpcnt(4) & fsmpcnt(5) are the sampling frequency divided by 32 and 64: used to verify the operation or cabling. When in low jitter operation, can be used to connect a frequency meter and verify that the reference clock is correct.
- Qclock is the internal quartz clock divided by 4 (20 MHz). Used to verify operation.
- GATEBASIC is the gating signal when operating in the "high rep rate" oscillator mode (gating option), see subsection 4.3.5.
- HWABUSY and HWSTROBE are handshake signals for the 'hardware addressing' option.
- SEQPARITY is related to the sequence option in burst mode. The signal is reset when waiting for the burst trigger. It increments on each sequence line.

8.8 Specifications

This figure describes the standard Dazzler^{TM}model availables. To download the specifications corresponding to one model, please go to our website: (http://www.fastlite.com). Custom systems are available upon request. Please contact Fastlite at info@fastlite.com.



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