MODBOX FE

User’s Manual

exail

Revision History

Table for the Software product (ModBox Interface Control):

Edition	Date	Release	Comments
I	09/2022	V4.2.1	• Add new amplifier support • NKT laser support and UI layout • Allow .csv filter format to have any number of column • "Valid filter file not found!" label now disappears when a valid file is loaded • Automatically unchecks "Filtering" checkbox when an invalid filter file is loaded • Automatically checks "Filtering" checkbox when a valid filter file is loaded • No longer attempt to load filter file when Canceling the open file dialog
II	28/02/2023	V4.2.2	• Add MBC trigger function
III	08/08/2023		• Add access to MBC external triggering on the back panel • New management of waveform correction and filtering • Modification of pulse generation including correction and filtering

Copyright

Disclaimer

exail specifically disclaims all warranties, either expressed or implied, included but not limited to implied warranties of merchantability and fitness for a particular purpose with respect to this product and documentation. exail further reserves the right to revise or make changes or improvements to this product or documentation at any time without notifying any person of such revision or improvements.

In no event shall exail be liable for any consequential or incidental damages, including but not limited to loss of business profits or any commercial damages, arising out of the use of this product.

Trademarks

Microsoft, MS-DOS and Windows are registered trademarks of Microsoft Corporation.

Intel and Pentium are registered trademarks and Celeron is a trademark of Intel Corporation.

Warranty

exail provides a standard warranty of one (1) year covering this product against any defect in materials or manufacture. The warranty starts from the date of shipment of the product from exail's manufacturing premises to customer's location and its duration is indicated in the certificate of warranty delivered with the product. In the event that a defect in materials or manufacture becomes obvious during the stipulated warranty period, exail will undertake, at its sole discretion, either to repair the defective product, bearing the cost of all parts and labor, or to replace it with an identical product.

In order to avail itself of this warranty, Customer must notify exail of the defect before expiry of the warranty period and take all steps necessary to enable exail to proceed. Customer shall be responsible for the packaging and the shipment of the defective product to the repair center notified by exail, the cost of such shipment being borne by Customer. exail agrees to bear the cost of return freight, based on CPT (Cost Paid To) Customer's airport location, import tax-free.

This warranty shall not be construed as covering defects, malfunctions or damages caused by improper use or inadequate maintenance of the product. Under no circumstances shall exail be due to provide repair or replacement under this warranty in order a) to repair damage caused by work done by any person not representing exail for the installation, repair or maintenance of the product ; b) to repair damage caused by improper use or connection to incompatible equipment, and specifically, the opening of the housing of the equipment under warranty shall cause the warranty to be automatically cancelled ; c) to maintain any product that has been modified or integrated into a larger configuration, if such modification or integration increases the duration or difficulty of the maintenance of said product.

This warranty covers the product hereunder and is provided by exail in place of all and any other warranty whether expressed or implied. exail does not guarantee the suitability of the product under warranty for sale or any specific use. exail's liability is limited to the repair or replacement of defective products, this being the sole remedy open to Customer in the event the warranty becomes applicable. exail cannot be held liable for indirect, special, subsequent or consequential damage, irrespective of whether exail has or has not received prior notification of the risk of occurrence of such damage.

Export Regulation

Export of the products and services described in this document may be subject to different national rules and regulations related to export control.
exail products and services shall not be exported, re-exported or used in the following countries (including their territorial waters): Cuba, Iraq, Iran, North Korea, Sudan and Syria.
The following export control guidelines shall apply as related to French rules and regulations.

Free export

This product or service can be freely exported.

Dual-use goods

Whenever the dual-use goods category applies, it has not been specifically developed for military applications but may be used in the scope of either civilian or military applications. It is then concerned by the dispositions of Regulation (EC) N° 428/2009 of the Council of 5th May 2009 as modified, directly applicable in French law.
As a consequence, this product or service is subject to the following dual-use goods export control procedures from France:

- It can be freely delivered to France or any country within EU.
- It can be exported under exail's Union General Export Authorization n° EU001 to the following countries (so called "bona fide"): Australia, Canada, USA, Japan, New-Zealand, Norway and Switzerland/Liechtenstein.
- It can be exported to other countries but only through the preliminary issuance of an individual export license by the French authorities.

If an individual export license has to be issued by the French authorities, it is required that you provide a description of your usual activity (and the one of the end-user if different) and that the end-user fills in an end-user certificate (using a predefined format). This certificate includes the description and location of the intended application for the product or service as well as a commitment not to re-export the said product or service without the preliminary agreement of the French authorities.
Once the product or service has been delivered to its first destination, the following rules apply:

- From an EU country member, the good is free of movement as long as it remains within EU.

- From an EU country member, the good can only be re-exported to a non EU country member under the dual-use goods export control procedures set forth by the local national authorities.
- From a "bona fide" country, the good can only be re-exported under the dual-use goods export control procedures set forth by the local national authorities.
- From another country, the good can only be re-exported under both the conditions of the original export license from France (depending on its type and content) and the dual-use goods export control procedures set forth by the local national authorities.

Manual Overview

This manual is the user guide for the ModBox Pulse system manufactured by exail. It must be read and understood prior to using the product. The manufacturer shall in no case be held liable for any application or use that does not comply with the stipulations in this manual.

It is divided into several chapters:

- Part 1: Introduction

This part contains a general description of the ModBox and provides information about the theory of operation.

- Part 2: Installation

This part gives some recommendations about the ModBox installation. It also details the procedure to install the ModBox system.

- Part 3: Configuring the ModBox

This part describes how the user should configure his ModBox system for a certain application

- Part 4: Operation

This part provides the full description of ModBox operation, and a description of the system's status and error messages.

- Part 5: GUI

This part provides a thorough description of the GUI used to control the ModBox system

- Appendices

It contains the detailed drawings and diagrams.

The abbreviations and acronyms used in this manual are listed hereafter.

Abbreviations and Acronyms

NIR	Near Infra-Red
MZM	Mach Zehnder Modulator
AWG	Arbitrary Waveform Generator
ATR	Acceptance Test Report
MMI	Man Machine Interface
NA	Not Applicable
SNR	Signal to Noise Ratio

Text Usage

Bold	Bold text is used for items you must select or click in the software. It is also used for the field names used into the dialog box.
`Courier`	Text in this font denotes text or characters that you should enter from the keyboard, the proper names of disk Drives, paths, directories, programs, functions, filenames and extensions.
Italic	Italic text is the result of an action in the procedures. It is also used for referencing to other document titles.

Icons

The **Note** icon indicates that the following information is of particular interest and should be read with care.

Important

The **Important** mention indicates that the following information should be read to forbid or prevent a product dysfunction or a faulty operation of the equipment.

The **Caution** icon indicates that the following information should be read to forbid or prevent product damage.

The **Warning** icon indicates that possible personal injury or death could result from failure to follow the provided recommendation.

The **Advanced/Expert** icon indicates that the described procedure/action is reserved to advanced level of operation.

Table of Contents

1 Introduction

1.1 ModBox Overview

ModBox systems are advanced modulation format optical transmitters, laser systems, sensing instruments and application specific modulation units.
In the ModBox systems, we use innovative optoelectronics setups with premium components to provide world class modulation solutions to our customers.
The ModBox systems address a broad variety of applications including but not limited to analog modulation, all digital format optical communication, ultrafast laser pulse generation, laser pulse picking, spectral broadening, etc.... We can also work towards custom systems to exceed some clients' specifications needs.
All modulation solutions come with the peace of mind of a bench top, plug & play equipment that can be remotely controlled using a pc.

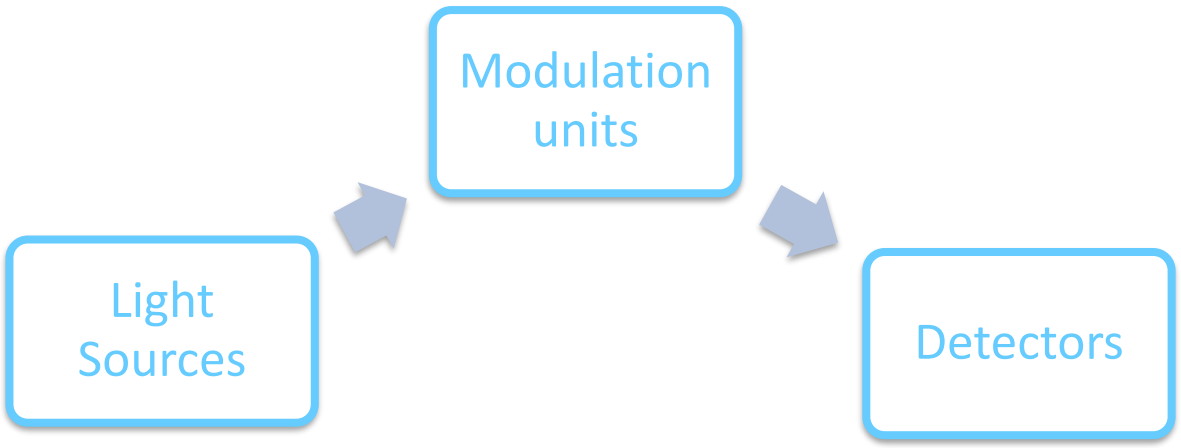


Figure 1 – Basic description of a ModBox system

1.2 Your ModBox system

1.2.1 INTRODUCTION

The ModBox Pulse Shaping is an optical modulation unit aimed at generating extremely short arbitrary shaped optical pulses with high extinction ratio in the NIR optical band. Minimum optical dynamic extinction ratio is 30 dB and can be up to 60 dB. The system allows complete freedom in terms of pulse duration, repetition rate and temporal pulse shape for optimized optical pulsed amplifier seeding for example. The ModBox Pulse Shaping fits very well front ends in high power laser system operating in a very strong saturated regime.

The system incorporates a modulation stage based on a set of large bandwidth custom designed Lithium Niobate Mach-Zehnder modulators with high performance electronics to enhance the operation stability of the system. Customers can select laser wavelength, extinction ratio and the pulse shaping capability that suit best the final application requirements.

The ModBox Pulse Shaping provides state of the art laser pulse shaping performance with the peace of mind of a turnkey instrument to R&D and production engineers. This system can be set as a reference tool in laser labs or as a seeder in laser amplifiers.

1.2.2 System Structure

The ModBox pulse shaping is a 19" 6U rackable modulation unit integrating:

- A modulation block
    - A large bandwidth optical modulation stage based on proprietary LiN_bO_3 technology
    - A set of high performance automatic bias controllers to ensure high contrast ratio stability with time
- Control electronics to operate the ModBox system either through the front panel or through the USB ports on the rear panel
- An AWG system aimed at generating the arbitrary optical waveforms
- A Delay generator to synchronize the ModBox system with other instruments in the lab

1.3 Theory of Operation

The ModBox Pulse shaping unit is a triggerable unit aimed at generating optical pulses with an arbitrary shape. The system carves CW or pulsed light with an arbitrary waveform. This can be done with a selectable repetition rate and with more than 60 dB extinction ratio.

The system can create shaped pulses from a CW laser source. The system can also pick optical pulses from a laser source satisfying the optical input conditions and shape them according to the user need. To achieve this the SMART system

embeds a triggerable delay generator that controls an AWG system that itself drives an optoelectronic unit that generate the high speed, high contrast ratio light modulation.

2 Installation

2.1 Checking the ModBox Pack Contents

You have just received your equipment in protective boxes. Before starting the installation, **we recommend checking the contents of the pack and the equipment immediately on receipt of your ModBox System**. Specifically, you should check that all items are present on delivery and that none has sustained damage.

For that, you will find in the shipping case a packing-list detailing all the shipped items. This packing list had been completed and checked for by exail shortly before shipment.

On receipt of the equipment, its overall condition should be checked and exail informed of any damage suffered during the loading operations. It is highly recommended to contact the insurance company in case damage is found.

Check that the shock label of every parcel is still white.

2.2 Transport

The ModBox System should always be transported in the package it came in.

2.3 Panel Features

2.3.1 FRONT PANEL

Figure 2: ModBox Front Panel

<1> LCD touch screen display:

Allows front panel system control and displays all necessary information to run the system

<2> Operation status indicator:

These led will lit green if the associated device next to it is turned on. This tracks the operation status of the seed laser, the booster amplifier, the AOM stages (acousto-optic based modulation level) and the EOM stages (electrooptic based modulation level).

<3> Alarm status indicator

These led will lit red if the associated device next to it has an issue. This tracks booster interlock status, key switch position status, seed output power status, current or temperature issues in the pumping stages of the booster system.

<4> Laser Key Switch

Enables/disables seed laser operation

<5> USB Ports

These USB ports may be used to attach a mouse, a keyboard or a USB memory stick. Keyboard and mouse may be used to control the windows based ModBox operating system. The USB stick may be used to transfer specific waveform traces.

2.3.2 REAR PANEL

Figure 3: ModBox Rear Panel

<1> Fans:

This ensures excess heat removal

<2> Scope:

This BNC connector may provide a synchronization signal for oscilloscope.

<3> SB:

This BNC connector may provide a trigger signal for a ModBox spectrum broadening unit.

<4> Amp:

This BNC connector may provide a trigger signal for a subsequent optical amplifier.

<5> Ext Trig:

This BNC connector hosts the incoming trigger signal to the ModBox system. This is intended to receive an external trigger signal (an electrical signal from a Photodiode for instance or from a master delay generator).

<6> Clock In:

This BNC connector hosts the incoming clock signal to the ModBox system. This is intended to receive an external clock signal (an electrical signal from a master clock).

<7> Interlock:

The Lemo type interlock connector needs to be connected to enable laser operation. Laser operation is allowed only when a 24 V signal is applied. A dry contact is included, closed when laser emission is on (open when no laser emission).

<8> Main Out:

This FC/APC patchcord delivers shaped optical pulses from the ModBox system.

<9> Internal Laser Out:

This FC/APC patchcord delivers CW light from the internal diode from the ModBox system.

<10> Main In:

This FC/APC patchcord receives either CW light from the internal diode from the port <11> or CW light provided by the user light source.

<11> Internal ground port:

This port connects to the internal ground.

<12> RJ45 ethernet port:

This port allows to connect the ModBox to a Local Area Network (LAN).

<13> Mains power supply socket and general mains switch:

Fuse socket accepts 5*20 mm sized fuse (2A, quick action)

<14> Auxiliary trigger signal output:

Aux 1, Aux 2 and Aux 3 provide a trigger signal for synchronization

<15> Auxiliary trigger signal output:

Aux 4 provides a trigger signal for synchronization. Connected to <16> MBC Ext. Trigger, it allows to inhibit the MBC voltage that controls the EOM bias in synchronization to the optical pulse.

<16> MBC Ext. Trigger:

This BNC connectors must always be connected to a 50 Ohm load for proper function of the MBC bias board. The 50 Ohm load is either the supplied 50 Ohm load or the Aux4 channel or the user delay generator.

<17> SB Ctrl:

This connector allows remote control of a Spectral Broadening unit.

<18> Amp. Ctrl:

This connector allows remote control of an external pulsed fiber amplifier.

<19> Reset Interlock:

The interlock can be reset by pushing the button in the case that only one of the 2 dry contact was open (door or interlock).

2.4General Recommendations

Make sure that the optical patchcords connected to the internal laser out & main in optical ports are cleaned. Failure to do so may induce optical losses and possible damage to the optical fiber end tips.

Make sure there is sufficient clearance below and behind the unit to ensure proper excessive heat removal by ventilation.

The ModBox is intended to operate from a power source that does not apply more than 265 V RMS between the supply conductors or between any supply conductor and the ground.

The ModBox chassis is connected to earth via the power supply cable. A protective ground connection by way of the grounding conductor in the power cord is essential for safe operation. A dedicated ground plug is available on the rear panel. In order to avoid potential injuries, insert the power cable only into a socket outlet provided with a protective earth contact. Before switching on the instrument, check that the electrical installation complies with the local safety requirements.

Only use specified power cord and connector for your product. This power cord should always remain in good condition.

To avoid personal injuries, do not operate this instrument without the protective cover of the chassis. Do not make any attempt to service or maintain the ModBox system.
Should you need any help, contact exail staff to get customer service support.

The ModBox is designed for indoor use. To avoid personal injuries do not expose the instrument to water or excessive moisture. Do not operate the instrument in the presence of inflammable gases or fumes.

2.5 Installation Procedure

During the installation process you may need the following document and devices:

- User's Manual
- ATR
- Country specific power cord
- exail ModBox USB key
- Ethernet cable

Step	Action
1.	Make sure the general mains switch is in OFF position (<10>, rear panel)
2.	Set the instrument on top of flat stable surface
3.	Make sure the air is allowed to circulate freely around the instrument to ensure proper cooling and to avoid dust accumulation (especially on the back of the system). **Caution** Failure to ensure proper cooling may affect ModBox performances and may induce damages to the system.
4.	Use the proper cord for your location
5.	Connect the end of the power supply cord to the ModBox rear panel power socket and plug the other end to the proper voltage mains supply point. The ModBox is equipped with self-regulating power supply that adapts automatically to AC 110V/ 60Hz and 220 V/50 Hz.
6.	For ModBox remote control, connect your control PC to the RJ45 ethernet socket located on the back panel, <15>.

2.6 Connecting the Components

Here we will describe how to connect the ModBox system to your application.

Step	Action
1.	Connect the Internal Laser Out to the Main In In optical connector located on the back panel though the fiber patchcord delivered with the system. Make sure that both ends of the fiber patchcord are clean before connecting them to the optical connectors.
2.	Make sure that the fiber patchcord Main Out (<8>, rear panel) is clean and is connected through clean optical fiber connector to clean optical fiber patchcords. Note that you should avoid bending the optical fiber patchcords as this may lead to power losses or even permanent damages to the optical glass. The Diag Out optical may be connected to a large bandwidth photodiode for preliminary tests. The Main out may be connected to an optical power meter for preliminary test. Note that it is advised to control the laser pulse energy before you connect it to your photodiode (especially if the photodiode is fiber pigtailed) and power meter.
3.	Using a BNC cable, connect your trigger signal (if applicable) to the Ext. Trigger input (<5>, rear panel). Trigger signal level should be comprised between 0.1 and 5 V. The trigger threshold is programmable through the ModBox interface.
4.	Using BNC cables, the user may connect other devices (oscilloscope, laser amplifiers, Pockels cells, ModBox Spectrum Broadening units …) to the independent delay channels provided at Scope, Sb, Amp and the 4 Aux #1-4 (AUX channels may **not** be included with your ModBox). Channels trigger configuration, delay, amplitude, and pulse duration are programmable through the ModBox interface.
5.	Connect the interlock plug in the interlock socket (<7>, back panel) to enable laser operation. A 24 V continuous voltage must be applied to enable laser emission.
6.	Make sure that the MBC Ext. Trigger (<16> see page 16) is connected to a 50 Ohm load: with the delivered 50 Ohm load, to Aux 4 (<15>see page6) or to your delay generator.

3 Configuring the ModBox

3.1 Software installation

Users can operate the ModBox system using the front panel and the software delivered with the system. The system is delivered with the software already installed so there is no need for the user to install the software.

Once the system is started, the ModBox interface application is launched, and the system is now ready for operation.

3.2 ModBox system configuration

The following section (3.2.1) applies **only** if your ModBox **includes** a Delay Generator

3.2.1 Internal or External Trigger Configuration

Configure the system using the procedure below, we consider that the physical installation and the connections have been completed.

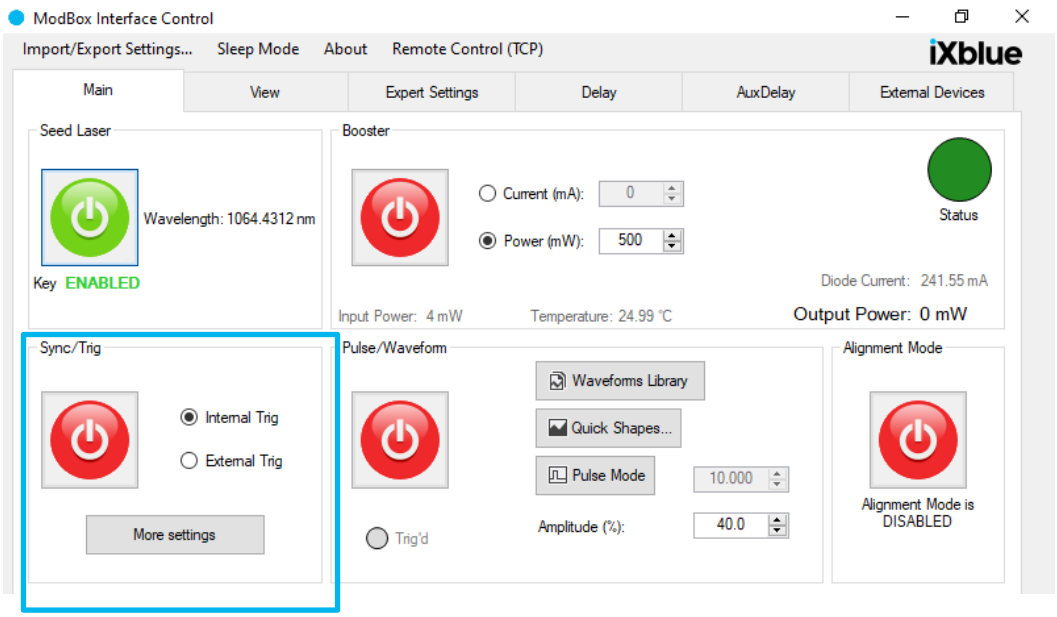


Figure 4: Trigger Configuration using the Main tab

Step	Action
1.	Turn on the ModBox general mains switch <13>, rear panel
2.	The ModBox control interface initiates the system. The ModBox control interface GUI appears, we will describe the GUI details later in that document.

Step	Action
3.	The system may be clocked by an internal or an external trigger. To do so you will choose in the **Sync/Trig** frame (bottom left of the **Main** tab) between the **Internal Trig** and **External Trig** trigger modes. You must then press the large red **ON/OFF** button, so it turns green.
4.	If you select the internal trigger mode, you don't need an external trigger signal to run the system. You need to select the system repetition rate on the **Internal frequency** frame located on the lower right corner of the **Delay** tab. There you would be able to select the operating repetition rate. You can enter a value between 1 Hz and 100000 kHz for the repetition rate value.
5.	If you select the external trigger mode, you would need to bring an external trigger signal. You would then need to adjust the trigger options in the "External trigger settings" frame located on the lower left corner to fit your application needs. You may adjust the trigger level threshold (from 0.1 up to 5V), polarity (rising or falling edge), and the prescaler ratio (from 1 up to 65535)
6.	Now the system is configured for either internal or external trigger conditions

3.2.2 CONNECTIONS

Here we describe the ModBox system front and back panel connections:

Figure 5: Front Panel connections

The user may attach a mouse and/or a keyboard to the system for easier browsing through the windows OS interface. Note that the system may also be controlled using the touchscreen display.
The user may also connect a USB stick to the system for file sharing using either one of the USB slot on the front panel

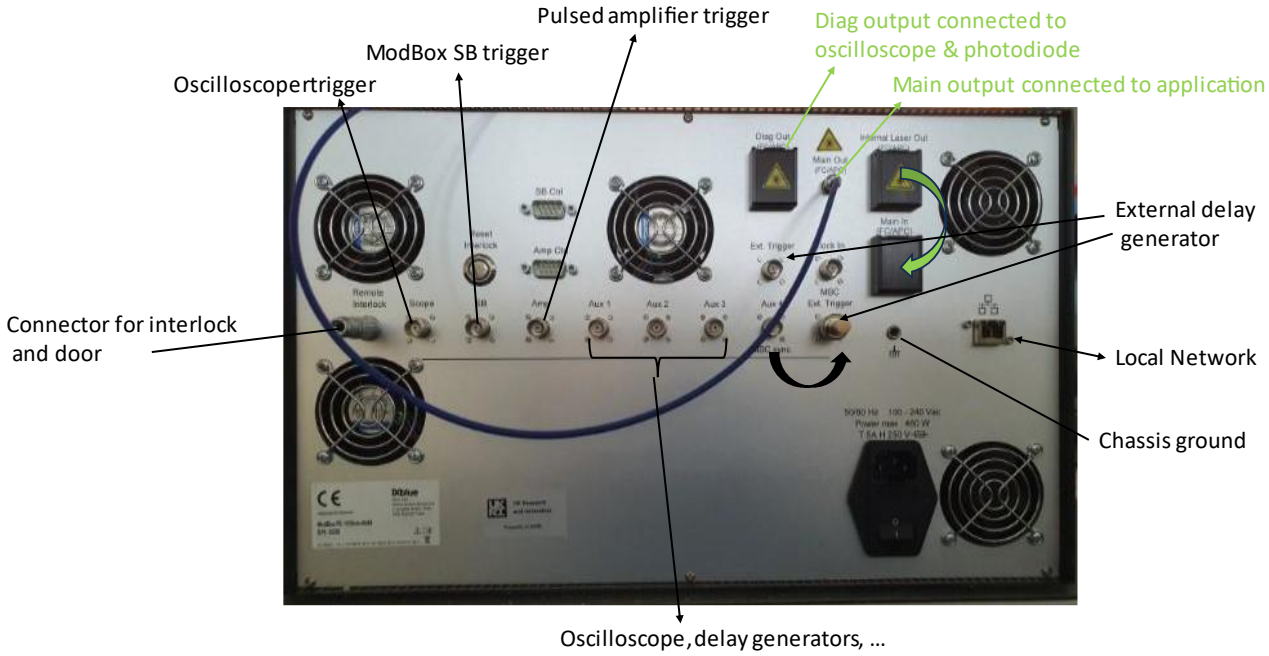


Figure 6 Backpanel connections

Please note that your ModBox may not include some of the stated devices.

The user may check the optical pulse using an oscilloscope and a photodiode with the following connection diagram.

An optical patchcord provided with the unit should connect the **"Internal laser out"** and the **"Main In"** optical ports: this signal is used for the system modulation loop control.

The **"Main Out"** fiber patchcord may be attached to a power meter using proper inline attenuation so that the Powermeter is not overloaded (which may lead to permanent damages if crossing the absolute ratings bounds).
The **"Diag Out" (not available** on all ModBox**)** fiber patchcord may be attached to a photodiode using proper inline attenuation so that the receiver is not overloaded (which may lead to permanent damages if crossing the absolute ratings bounds).

Note that the interlock connector should be in place for laser operation: it won't be possible to run the booster amplifier as long as the interlock is not attached to its **"Remote Interlock"** slot.

If your ModBox includes a Delay Generator: the oscilloscope trigger port should be connected to the **"Scope"** delay channel. The ModBox Spectrum Broadening unit input trigger should be connected to the **"SB"** delay channel. Any subsequent optical amplifier with a trigger input requirement may be connected to the **"Amp"** delay channel. Depending on your ModBox order, there may be 4 delay channels available for instrumentation synchronization if needed, they are labelled Aux X with X in the range [1,4].

Note that the user may attach an external trigger signal to the **"Ext. Trigger"** BNC port if he intends using the system in external trigger mode. Alternatively, the system may be run in internal trigger mode by a simple configuration recalled in the previous section.

MBC Ext Trigger must be connected to a 50 Ohm load to enable MBC proper operation.

Finally, the system may be connected to a local network for remote control using the Ethernet socket on the back-panel.

4 GUI Operation

We consider here that the user has installed the hardware items related to the ModBox system. We also consider that the user is familiar with ModBox configurations and that the ModBox configuration is presently set.

4.1 Operation procedure

Step	Action
7.	Turn on the ModBox general mains switch <16>, rear panel
8.	The ModBox system will initialize and check critical components operation. The following screen will be displayed after the ModBox interface has controlled the hardware conditions and settings:

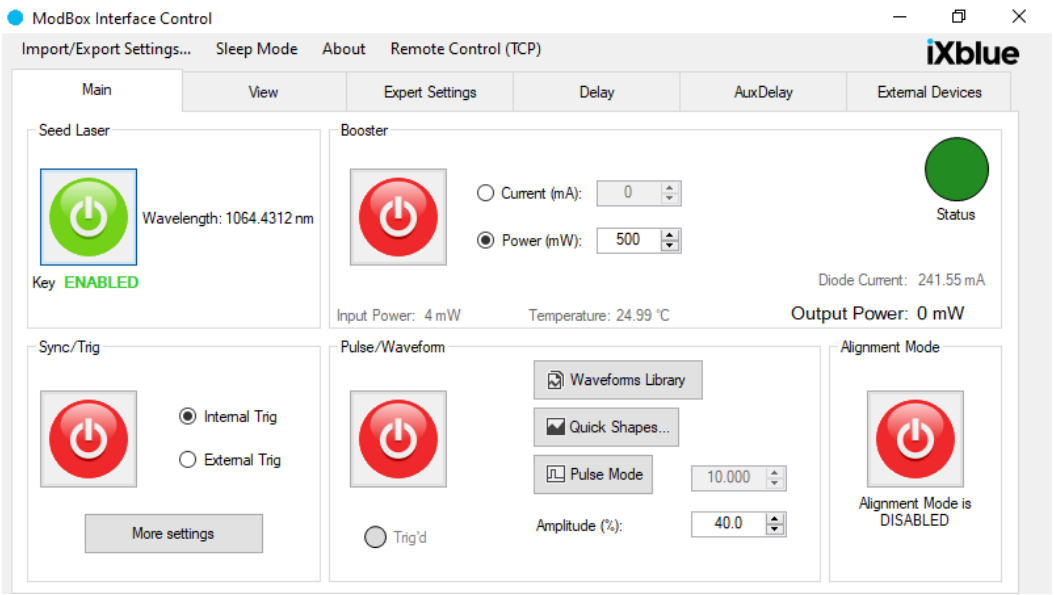


Figure 7: Main Tab

First, we need to start the seed laser:

To do that you need to take a closer look to the **Seed Laser** frame located at the left upper corner of the Settings tab.

You may enable the laser seed by pressing the large red ON/OFF button (do not forget to also set the key switch on the front-panel to the EN position). Laser emission is not possible unless a 24 V continuous voltage is present on the remote interlock connector <7> on the back panel.

Step	Action
9.	Now we need to start the power amplifier also called Booster. To do that you need to take a closer look at the **Booster** frame. This frame has a radio button that allows 2 choices: Current(A) and Power(W). If set to **Current(A)** the booster operates in constant current mode and the set current value (in the numeric box to the right of the Current(A) label) will be kept constant by the system. If set to **Power(W)** the booster operates in constant power mode and the set power value (in the numeric box to the right of the Power(W) label) will be kept constant by the system. Note that only one mode can be select at a time. The Input Power and **Output Power** labels in the same frame display the actual input power and the actual output power from the booster perspective. The green/red circle on the right of the frame display **alarms** that may happen during booster operation. If the circle is green, no alarms were triggered. If it is red however, one or more of the following issues may be displayed: - **Interlock**: the interlock is not plugged in the back-panel socket or a 24 V is not applied on the interlock. - **Key**: the virtual software key switch needs to be reenabled. This is done by clicking the software key switch on the right of the ON/OFF button. - **Seed**: the laser seed power is too low for proper operation. You should also check that the physical laser key on the front-panel is set to the EN position. - **Preamp Cur.**: There is an issue with the preamplifier stage diodes injection current. - **Booster Cur.**: There is an issue with the booster stage diodes injection current. - **Preamp Temp.**: There is an overheating issue with the preamplifier stage temperature. - **Booster Temp.**: There is an overheating issue with the booster stage temperature.

Step	Action
	To set the Booster on, set the virtual key switch to the EN position (by clicking the EN/DIS key icon), then press the large red ON/OFF button. When disabling then reenabling the virtual key switch, any triggered alarm or fault should be reset and should disappear if they are no longer relevant. Note that you cannot switch from one operation mode to another if the Booster is ON. You would need to stop the Booster, change the operation mode from current to power control or the other way around and then restart the booster.
10.	The following section is relevant only if your ModBox **includes** an Arbitrary Waveform Generator. (if it does not, please see section 11) Now the laser is operating, and we need to start the pulse shaping engine: we will need to take a closer look at the **Pulse/Waveform frame**. Press the large red ON/OFF button on the left: the button will turn green and the pulse shaping engine will be on. Below that button is a small led labelled **Trig'd**. When this led turns green, that means that the AWG is being triggered. The RF driver amplitude(s) may be changed from this frame or from the **Expert Setting** tab. As the name suggests, you can instruct the device to output either a **Pulse** or an arbitrary **Waveform**. Even though a pulse can be seen as a specific square waveform, a small distinction is made because a generating a pulse is slightly easier to handle by the ModBox. For this reason, the application can be set to "**Pulse Mode**" if what you need is a simple pulse signal by using the third button of the frame (Figure 8, left). This enables the Width setting on the right of where the button was (Figure 8, right).  *Figure 8: Pulse Mode button and Pulse Width setting* If set to **Pulse Mode**, the system will produce square pulses with **Pulse Width (ns)** width and maximum amplitude (by default). The width ranges from 125 ps up to 100 ns and can be adjusted in 125 ps steps. The Pulse amplitude level

Step	Action

range from 0 to 4095 (12 bits dynamic range) and can be changed in the **Expert Settings** tab.

The Pulse Mode is **automatically disabled** whenever an arbitrary waveform is sent, using one of the other two buttons (described below), or by following the instructions described in the section 12.

The second button called **Quick Shapes...** can be used to display the following window:

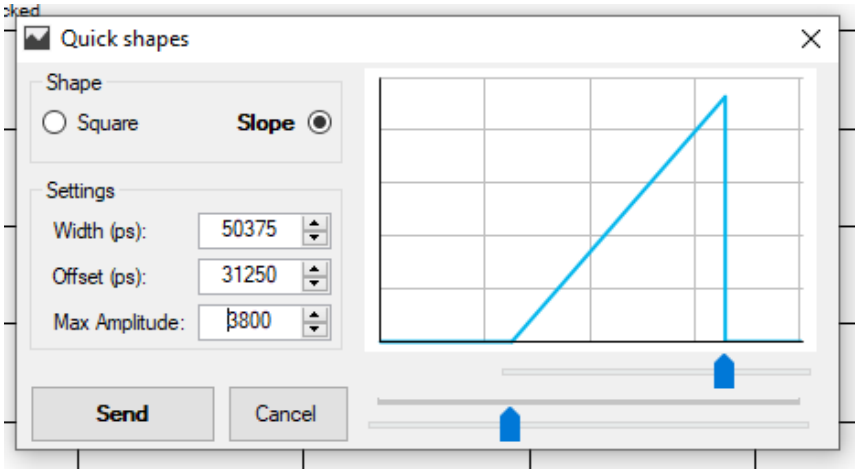


Figure 9: Quick Shapes window

This tool can help you to create either a **Square** shaped waveform or a **Slope** shaped one. You can customize the **Width** of the shape and its beginning (**Offset**) by using either the numeric boxes on the left, or the sliders under the chart preview on the right.
For advanced needs, you may also change the height (**Max Amplitude**) of the shape (which defaults to the Max Pulse Amplitude setting in the Expert Tab).

Pressing the **Send** button will close the window and send the chosen shape as a waveform to the EOM (you do not need to press the **Send Waveform** button afterwards).

Finally, the first button, **Waveforms Library**, allows you to open a collection of previously saved waveform files, displayed in a browsable library (Figure 10).

To choose a waveform, double press its preview or press it once then click the **Load** or **Edit** button. The waveform will then be imported to the View tab of the main window, where you can send the waveform as is, or alter it beforehand. If you clicked the **Load** button, the waveform will also be sent immediately. Detailed instructions of this tab are given in the section 12.

Step	Action

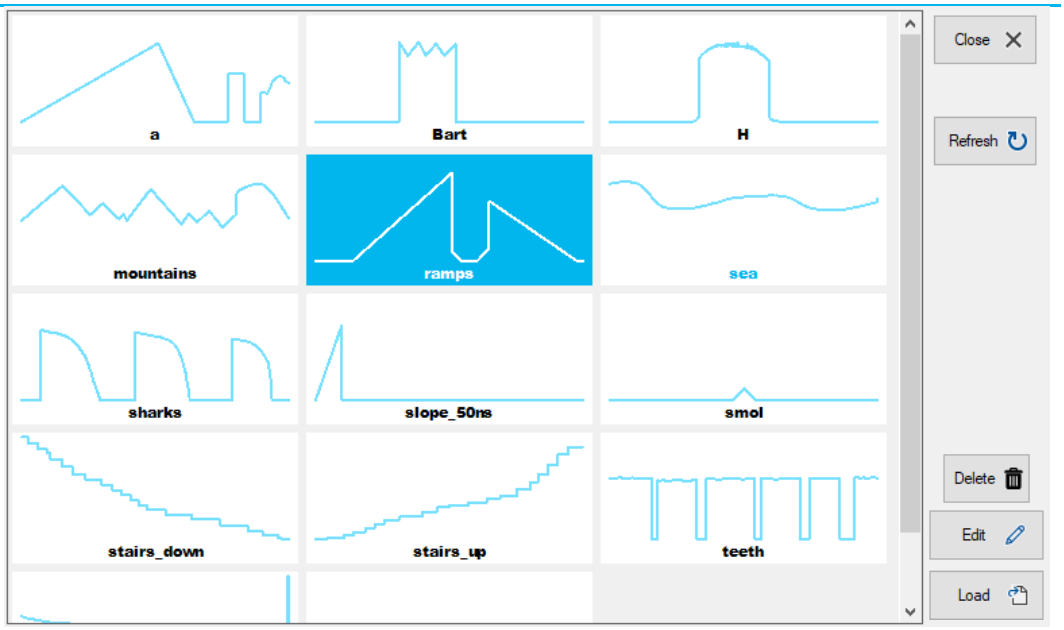
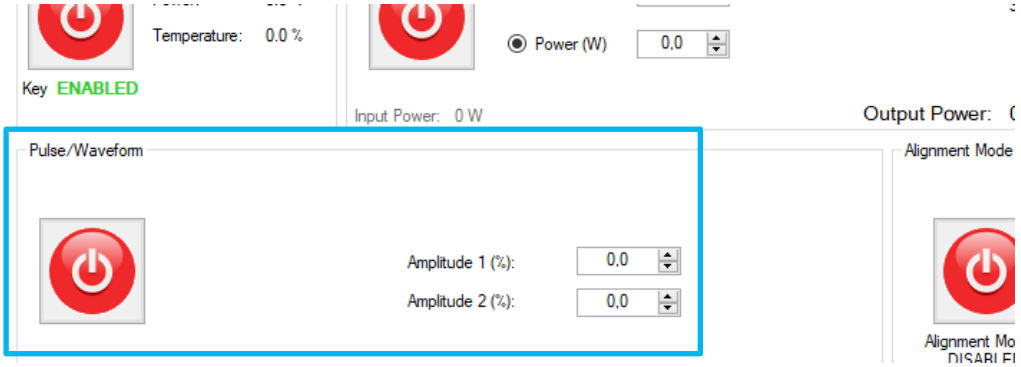


Figure 10: Saved Waveforms Library

The source of this library is a folder on the Windows Desktop called "**Saved Waveforms**". This directory contains the actual text files that are loaded from the library window. You may manually copy from / to this folder as you wish, or rename files, but the folder must not be renamed or moved (or it will be recreated, and the library will be empty).

Adding waveforms to this library, as well as an alternative way of producing waveforms from the GUI, are described in the section I2.

II. <u>The following section is relevant only if your ModBox **does not** includes an Arbitrary Waveform Generator.</u>



Now the laser is operating, and we need to start the RF engine: we will need to take a closer look at the **<u>Pulse/Waveform frame.</u>**

Step	Action

To do that the user need to press the large red ON/OFF button: the button will turn green and the RF driver(s) will turn on.

The RF driver amplitude(s) may be changed from this frame or from the **Expert Setting** tab.

12. <u>The following section is relevant only if your ModBox **includes** an Arbitrary Waveform Generator.</u>

Select the View tab from the menu bar, the following screen will be displayed:

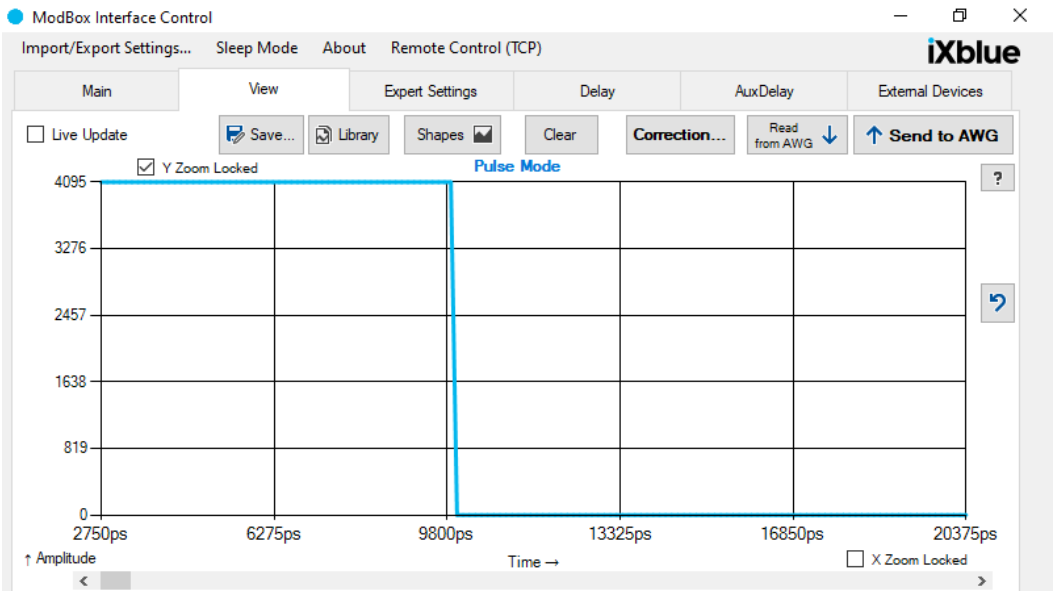


Figure 11: View Tab (graphical waveform drawing tool)

The screen is composed of several controls (one checkbox and six to seven buttons) on top of a graphical area representing arbitrary waveforms.

From the available controls on the top, you can find the following seven buttons: **Save...**; **Library**; **Shapes...**; **Clear**; **Correction**, **Read from AWG**; **Send to AWG,** and one checkbox: **Live Update**.

As mentioned in the previous paragraph, it is possible to draw waveforms directly from the graphical area using a mouse or the touchscreen (Although using a mouse would provide enhanced precision):
The graph vertical scales (labelled "Amplitude") extends from 0 to 4095 (pulse amplitude level coded on 12 bits) and the graph horizontal scale (labelled "Time

Step	Action

(ns)") ranges from 0 to 100 ns (the maximum programmable pulse length is 100 nanoseconds).

Note: depending on your order, your ModBox may have been set to have an increased maximum programmable pulse length (usually, up to ~511ns).

The user may draw a pulse by maintaining the mouse left button pressed while drawing the waveform using the mouse icon on the graphical area, the waveform will be drawn in blue color. Once the drawing is finished, the user may just release the mouse left button. If the user is not satisfied with the drawing, he may use the **Undo** button  on the right of the graph. Alternatively, the drawing can be erased (i.e. every sample in set to 0) using the **Clear** button.

For more advanced features on the graph (like drawing a straight line or zooming), click the **help button**:  (top right corner).

The **Library** button has the same effect as the **Waveforms Library** button in the main tab.
The **Shapes…** button has the same effect as the **Quick Shapes…** button in the main tab.

The **Correction…**button covers 2 functions. The first one is **Filtering** which will apply a calibrated temporal filter to increase the linearity of the pulse shaping based on advanced modeling of the EO modulator. The second is **Nonlinearity** which correct the sinus transfer function of the EO modulator. **Order** value should be selected to 2 (one EO modulator in the ModBox) or (two EO modulator in the ModBox).
We recommend using them both if high fidelity pulse shaping is required for the application.

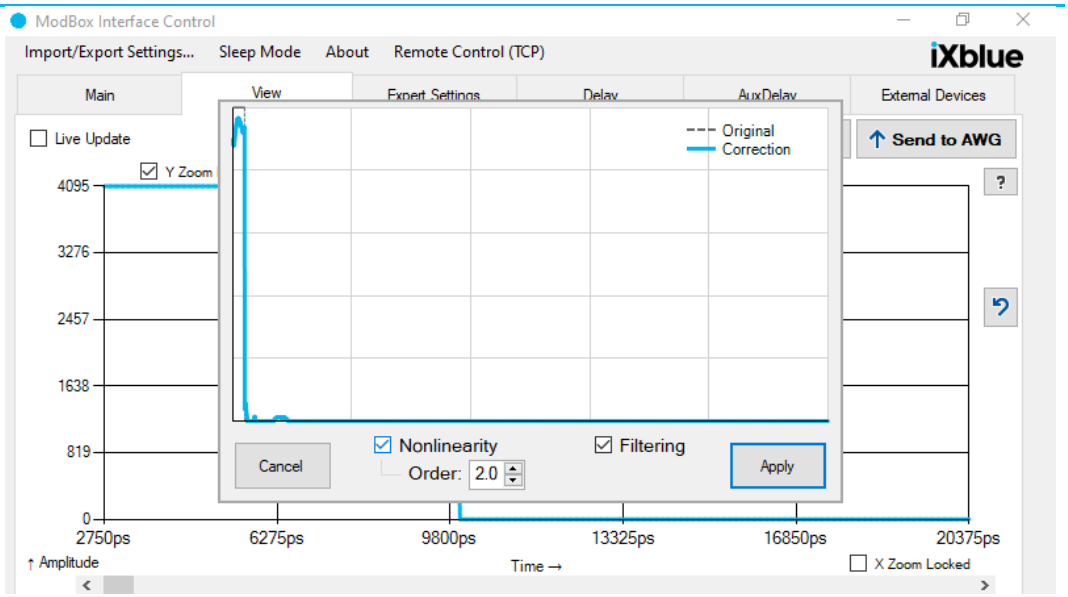


Figure 12 Correction button

Once you have drawn or loaded the waveform you want, it may be loaded in the system's memory: this may be done by pressing the **Send to AWG** button.

The system now generates the programmed waveform.

The current waveform (in blue color) can be saved as a text file by pressing the **Save...** button. A small input dialog will pop up to choose a name for the file to be save the waveform's samples in.
To be fully compatible with the remote control, try to **avoid special symbols & characters** (e.g. @, $, €, accentuated characters, commas, colons, ...). However, you can use **Spaces**, **hyphens,** and **underscores** without any issue.
Those saved waveforms are in the "**Saved Waveforms**" directory on the Windows' Desktop, and will now appear in the **Waveforms Library**

You can check the actual system's memory content, by using the **Download from AWG** button. Then the blue signal will be replaced.

Live Update Mechanism

When the **Live Update** checkbox is checked, any new point drawn on the chart will be updated as soon as possible on the EOM output. Please note that updating several points in a small lapse of time may take some time, so it is recommended in that situation to uncheck the **Live Update** setting and use the **Send to AWG** button instead.
In the event where a lot of point were changed with the checkbox enabled, it is still possible to cancel the operation by clicking the **Abort** button. This button

Step	Action

only appears when several updates are pending. Clicking this button will finish the current update then download the waveform from memory.

If the Optical Correction has been enabled, then even when using the Live Update feature, a correction is applied to the changed point.

13. The **Alignment Mode** can be enabled or disabled using the matching button:

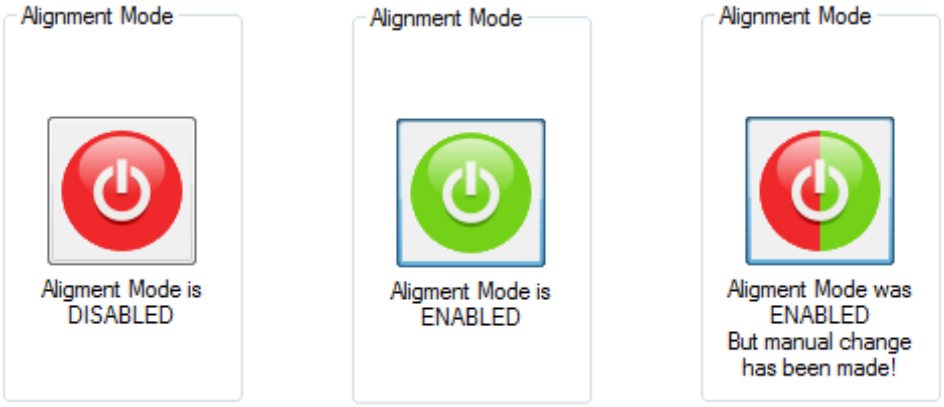


Figure 13: Alignment states

Enabling the Alignment Mode has the following effects:

- Turn OFF the AWG
- Enable the delay generator (Sync/Trig) in the Internal Trig mode
- Set both MBCs' Transfer Level to MAX (Expert Settings tab)
- Set both MBC's Dither Amplitude to 100 mV (Expert Settings tab)

Disabling the Alignment Mode restore the above settings to their original values (before the mode was enabled) except for the AWG's state (it remains turned OFF).

Step	Action
	If one of the above values is manually changed while the mode is enabled, the button will reflect an indeterminate state (third picture above).

14. The following section is relevant only if your ModBox **includes** a Delay Generator.

In order to get optical pulses out of the system, we need to start the system's trigger engine in the **Delay** tab.

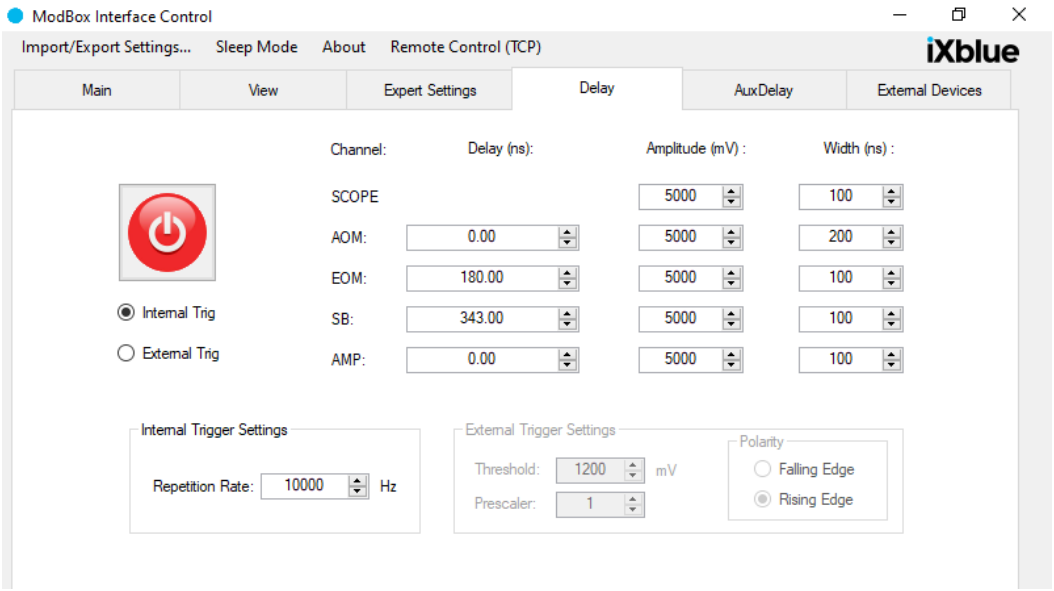


Figure 14: Delay Tab

The **Delay** tab displays the actual delay control setting for the delay channels available from the system. There are 5 delays channels available from the **Delay** tab and (if your ModBox includes AUX outputs) 4 other auxiliary delay channels from the **AuxDelay** tab.

The Configuration for the whole setup should have been defined in the previous section: ModBox System Configuration. If you intend to run the system as a standalone unit, you should set the internal repetition rate. This may be done by selecting a repetition rate between 1 Hz and 100 kHz in the **Repetition Rate** numeric box of the **Internal Trigger Settings** frame located on the lower right corner. If you intend to trigger the system using an external repetitive signal generator, you will need to adjust the **External Trigger Settings**: the user may set the Level Threshold, the trigger signal polarity and the internal prescaler ratio number.

The Level threshold may be tuned by setting accordingly the **Threshold** numeric box. Values between 0.1 V and 5 V per mV steps can be set. The external trigger polarity may be set using radio buttons: triggers on falling edges or on rising edges are available. The embedded prescaler allows the user to trigger the system at a lower repetition rate. If set to 10, the system will actually output a signal only once per 10 trigger events detected. This is done by setting the External pre-scaler parameter numeric box, values span from 1 to 65535.

The different delay channels parameters are detailed in 4 columns: configuration, Delay (ns), Amplitude (mV), Width (ns).

The configuration has been detailed adjust above and stands for all channels displayed on the Delay tab namely: **SCOPE** (signal to trigger an oscilloscope or other analysis system), **AOM** (the internal acousto-optic modulator stages), **EOM** (the internal electrooptic modulator stages), **SB** (spectrum broadening unit if applicable), and **AMP** (stands for amplifiers). The channel delays are respective to the scope channel. The scope delay channel is fixed and is the reference to the other delays in the system. The Scope channel delay is not tunable, and the amplitude is also fixed at 5V. Only the width may be tuned if necessary, the standard width is 100 ns. For the AOM, EOM, SB and AM channels, delays, amplitude, and widths may be adjusted. Delays may be adjusted from 0 to 20 s. Widths may be adjusted from 100 to 10000 ns (this upper bound may vary on your ModBox). Amplitudes may be set from 2000 to 5000 mV.

Important

The Delay Generator **cannot be turned ON** if the ModBox System determined that the AOM safety is at risk (i.e. the AOM would receive too much power).

If this happens, try **decreasing** the following settings (when this safety is triggered, the settings will be highlighted with a red border):

- Booster Current / Power
- Repetition Rate *(when using the Internal Trig mode)*
- AOM Width

Note that delays have been set at the factory and that no further adjustment should be required. The AOM and EOM channels settings should not be modified.

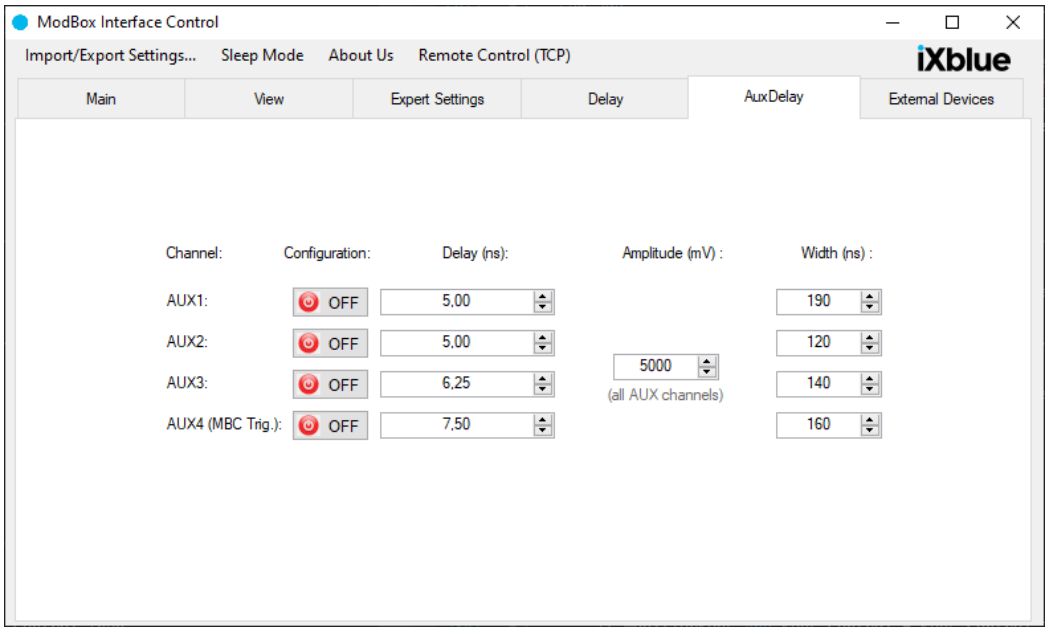


Figure 15: AuxDelay Tab

The Auxiliary delay tab: "**AuxDelay"** provides 4 added channels. Your ModBox does **not necessary** include AUX outputs. Here there are only 2 choices for the configuration: ON or OFF. The Auxdelay tab channels share the trigger configuration of the Delay tab channels. If the delay channels are set Internal trigger configuration, the auxdelay channel will also be set for internal triggering.

Note that the AuxDelay channels can't be activated if the main delay channels configuration is turned OFF.

Note that the amplitude setting is shared by the 4 auxiliary channels. Delays and width are tunable per channel. Delay can be set from 0 to 20 s, and width from 100 to 10000000 ns.

The AUX4(MBC trig) is dedicated to the triggering of the MBC (Modulation Bias control). If AUX 4 is turned on, the MBC is synchronized to the EOM to suppress the dither voltage applied to the EOM. It improves the optical pulse stability. Aux 4 width must be set to 500 µs and all delays in the delay tab (Figure 13: Delay Tab) must be increased by 450 µsec compared to factory settings to compensate for MBC internal delay. Please note that using the MBC trig limits the ModBox repetition rate to 500 Hz maximum.

15. Let's take a closer look at the **MBC Settings** in the Expert Settings tab:

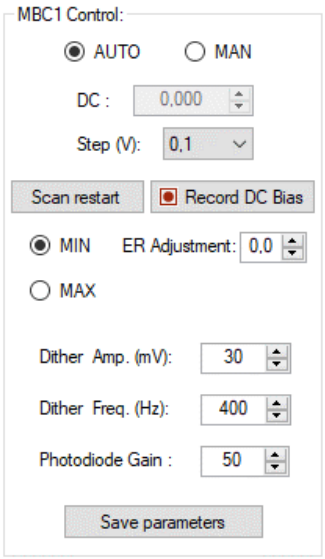


Figure 16: MBC Settings in the Expert Settings Tab

MBC stands for Modulation Bias Control. The **MBC Control** allows the user to control the modulation stage control.

The user can select the control type: **auto**matic or **man**ual by selecting the corresponding radio button.

In case manual control has been selected, the user can enter the bias value in the "**DC**" labelled textbox just below the radio buttons. The step value (increment added each time one of the up or down arrow is pressed in the DC textbox) may be tuned in the "**Step**" labelled textbox. The input value is in V units.

In case automatic control has been selected, the user may select minimum or maximum transmission as the locking polarization setpoint of the modulators by selecting the appropriate radio button. The user may initiate a scan restart by pressing the "**Scan restart**" push button.

On some ModBoxes only, an **ER Adjustment** setting is available. Unless explicitly advised by exail, we do **not** recommend changing this value.

The **Record DC Bias** button opens a new window to monitor the DC bias value:

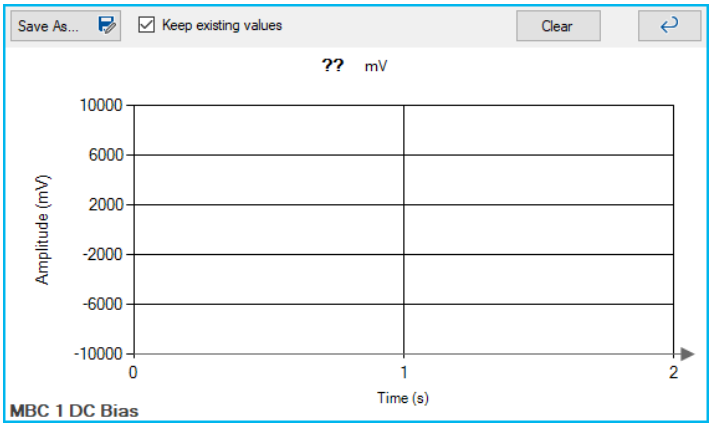


Figure 17: Record DC Bias window

This window is moveable, and the user can still interact with the main window. The **Save As...** button will save the monitored DC bias values into a text file (a dialog pops up to select the filename). If **Keep existing values** is checked, any values present on the chart will be added at the beginning of the file.

The **Clear** button remove all the values from the chart.

The **Return** button (with an arrow) closes the window.

The MBC loop control uses a dither signal that is applied to the DC electrodes of the modulator in order to dynamically sense its real-time polarization setpoint.

If we go back to the **Expert Settings** tab, the dither signal may be tuned in amplitude and frequency. The **Dither Amp** textbox allows the user to finely tune the amplitude in mV. The **Dither frequency** textbox allows the user to finely tune the frequency in Hz.

Finally, the "**Save parameters"** pushbutton located in the bottom allows the user to save dither and photodiode MBC settings.

If your ModBox includes two MBCs, the same controls are available for MBC2 since there are 2 completely independent control loops for both modulation stages.

Note that it is recommended to leave the MBC settings unchanged unless under guidance of exail service department.

The MBC can also be triggered to stop the dither signal when an optical pulse is generated. See section 14 on how to activate the function.

16. You should now be getting optical pulses on your oscilloscope if you did connect the ModBox output to a photodiode. Please make sure that the flux directed at the photodiode does not exceed its maximum ratings.

Note that depending on the optical pulse width, you may be able to optimize the pulse shape using the **Expert Settings** tab.

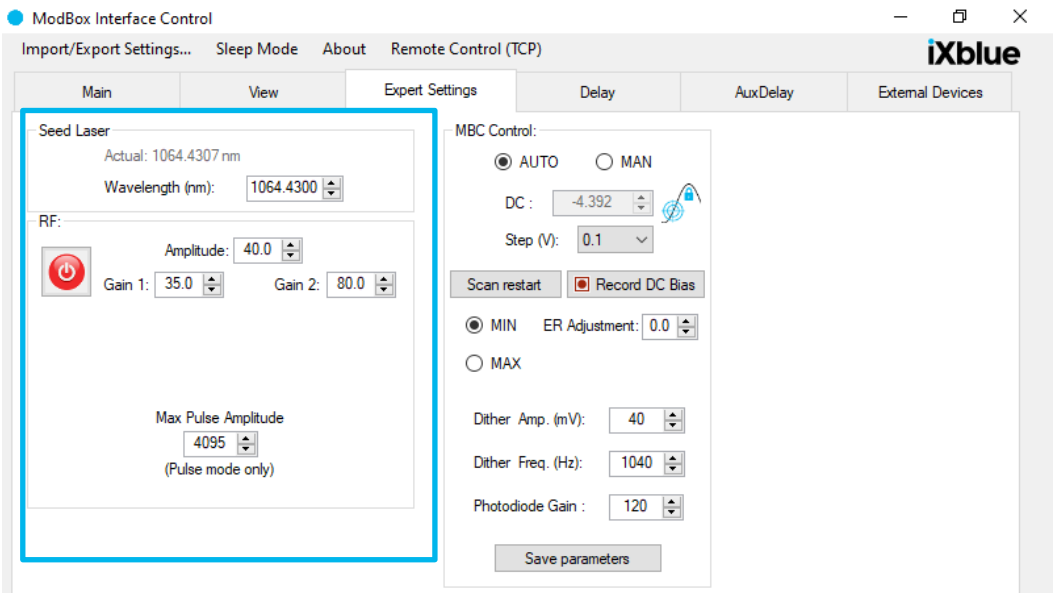


Figure 18 The Expert Settings Tab

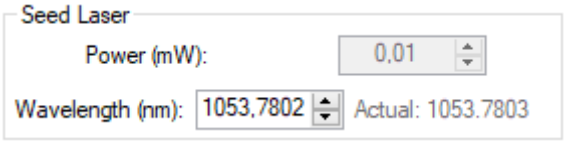
The **Expert Settings** tab is composed of 2 to 5 frames: the MBC frame(s) (as seen before), the **Seed Laser** frame, the **RF/Optical Correction** frame (only if your ModBox includes an AWG), and the **Step Channel** frame (only if your ModBox includes an AWG and only one RF Driver).

Note that the **Optical Correction** frame apply to the user programmed waveform.

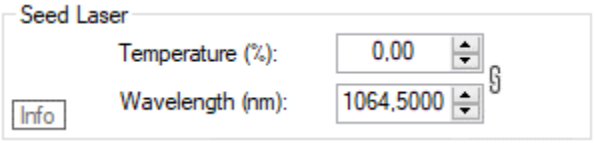
The **Amplitude** parameter in the **RF** frame(s) allows the user to finely tune the pulse shape; Values range from 0 to 100%. The system comes with an optimized value. If you intend to use this feature, make sure that the values are close to the factory optimized setting.
Two additional parameters are available for even further fine tuning: **Gain 1** and **Gain 2**. We recommend against changing them, unless explicitly requested by exail support.
The **ON**/**OFF** button on the left controls the matching RF driver's state. Check the box to turn it ON, uncheck it to turn it OFF.

(Only if your ModBox includes an AWG) The **Optical Correction** frame contains an **Enabled** Checkbox. When this box is checked, the pulse shaping data are pre-processed to account for nonlinearities from the optical and RF modulation. The default value is 3, you may finely tune this value again. Just make sure that the newly set value does not depart too much from the factory optimized setting.
Changing this value automatically updates the orange signal in the **View** tab.
The **Max Pulse Amplitude** setting specifies the maximum amplitude to use when sending a pulse to the EOM output (in the **Main** tab).

The **Seed Laser** frame's content may vary:
If you ordered the *Low line-width* option, you may use this frame to adjust the wavelength of the seed laser. Please note that adjustments may take a while (the "Actual" value displays the wavelength measured by the laser). The displayed wavelength is given in Vacuum for low line width option.



If you do not have this option, the frame is similar; the wavelength can be adjusted indirectly by changing the **Temperature** setting of the Laser from 0 to 100%. Alternatively, a calibration was made to give an estimation of the actual **Wavelength**. Those two settings are linked, changing one updates the other.



The following paragraphs (about **Step Settings**) are relevant only if your ModBox includes an AWG and only two RF Driver.

For enhanced contrast, we use 2 modulation stages, one of them is driven to provide a simple optical square gate that will then be carved by the user programmed waveform. The modulation stage that generates the optical

square gate is called the **Step Channel**. The control settings for this optical square gate are in the **Step Channel** frame.

The optical gate may be tuned in amplitude, in width and in delay with respect to the arbitrary modulated pulse. These values may be tuned using the **"Step Amplitude (mV)"**, **"Step Width (ps)"** and **"Step Delay (ps)"** parameters and their corresponding numeric textbox located to their right side. The amplitude is set in mV, the delay and the width in picoseconds. The amplitudes range between 0 and 5000mV, the widths range between 2000 and 120000 ps and the delays range between -2000 and 120000 ps.

The **"Step delay"** is optimized with respect to the beginning of the arbitrary waveform memory: i.e. the value is finely tuned so that the first sampling point (of the programmed waveform) is matched in time with the beginning of the optical square gate. Note that if your waveform doesn't start from the very first point in waveform memory then there will be an added shift between the optical square gate and the programmed waveform (this shift would amount to the number of samples prior to the waveform start). This may be corrected by changing the delay setting.

The **"step width"** should be tuned with respect to the intended programmed waveform width: they basically should share the same width (the optical gate should actually be a little bit longer than the actual programmed waveform so that the programmed optical pulse wouldn't experience fading on the edges).
The **"step amplitude"** should be optimized to generate the cleanest square optical pulse. The value may need some fine tuning when the **"step width"** changes. The amplitude should be increased towards shorter width.

17. The following section is relevant only if you ordered tour ModBox **with** external Spectrum Broadening and Pulse Amplifier devices

Both devices can be controlled using the **External Devices** tab.

Important

The devices must be connected to the ModBox (using the provided RS-232 cables) **before** starting the GUI. If not, the devices will not be recognized by the software.

While the GUI is running, it is highly **recommended** that you keep both devices connected to the ModBox **and Powered ON** to prevent any desynchronization in the data displayed on the GUI.

If the Pulse Amplifier device is disconnected (or turned off) while the GUI is running, you will need to **restart** it to restore communication.

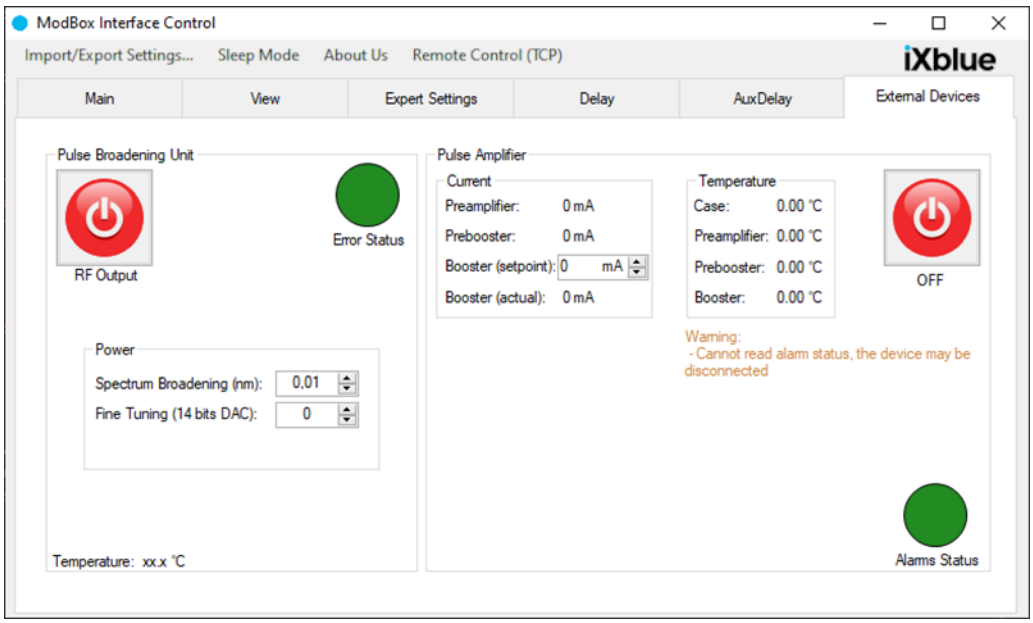


Figure 19: External Devices Tab

On the left part of the tab, the **Pulse Broadening Unit** frame allows you to turn **ON** or **OFF** the RF Output of the device (top left button) and change its **Power**.

There are two input boxes that both change the power setting, and changing one updates the other.

The most accurate setting is the second one (**Fine Tuning**), since this is the true value that is sent to the external unit. It ranges from 0 (Maximum broadening effect) to 16000 (Minimum broadening effect).

On top of this, the **Spectrum Broadening (nm)** input box allows you to directly select a broadening width. Your ModBox has been calibrated to link every step of 0.01 nm (from 0 to ~0.3nm) to a specific DAC value.

The frame also provides some information such as the **temperature** inside the device and the **current faults** detected by the unit.

The detected faults can be one or more of the following:

- Grid Voltage
- Power Output
- External Trigger
- RF/Optical Synchronism

If one or more of these issues are detected and displayed, the green circle (top right of the frame) turns **red**.

The message "PLL" can also appear with the above faults, though it is just a warning to inform that the PLL input on the device is not used. Be aware that this warning still triggers the physical red LED on the front-panel of the device.

On the right part of the tab, you will mostly find information about the current state of the **Pulse Amplifier**. In the bottom right corner, errors and warnings reported by the device will appear, and the circle turns **red** in the case of one or more errors.

In this frame, two settings can be changed. The large button in the top right corner controls the **mode** of the device: either **OFF** or **ACC** (**A**utomatic **C**urrent **C**ontrol).

The **Booster (setpoint)** changes the current used by the amplifier (its actual measured value is displayed right below it).

18. The ModBox system is now ready for use in your application.

4.2 Menu bar

A menu bar at the top provides additional functionalities: **Import/Export Settings…**, **Sleep Mode**, **About**, and **Remote Control**:

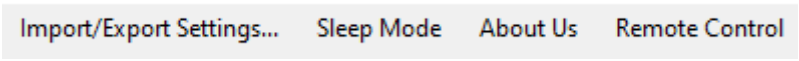


Figure 20: Top Menu Bar

Clicking the **Import/Export Settings…** menu item will open a dialog to choose the settings you want to export or load. .ini files are used to store and load settings.

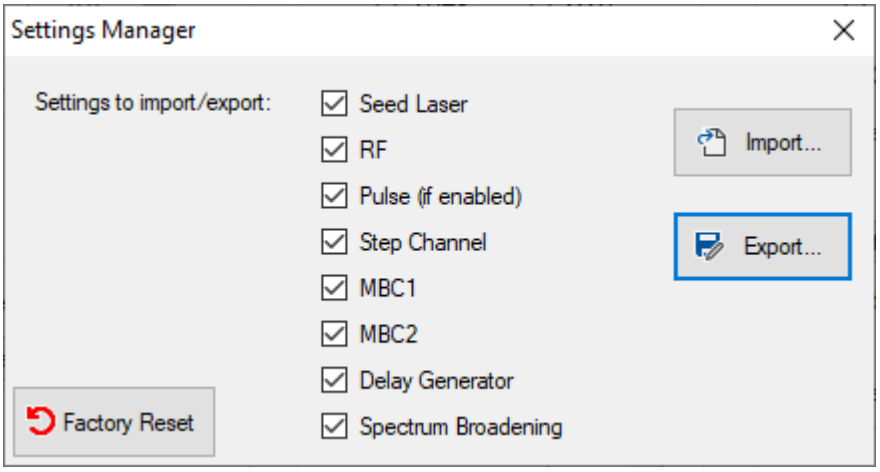


Figure 21: Example of Settings Manager dialog to export or import selected settings

This dialog also contains a **Factory Reset** 

button.

Pressing this button will (after prompting you for confirmation) **load** almost every setting back to its **factory value**.

The **Sleep Mode** menu item allows the user to set the ModBox system in an idle position. The system can be switched between **Sleep ON** and **Sleep OFF**.
The internal components are switched off during sleep mode but may be reactivated at any time. This feature is very handy if the system needs to be interrupted for a short amount of time (lunch break, meetings …).

The **About** menu bar item displays company information and ModBox interface application identification data. Legal information is also available in the **Licenses** tab.

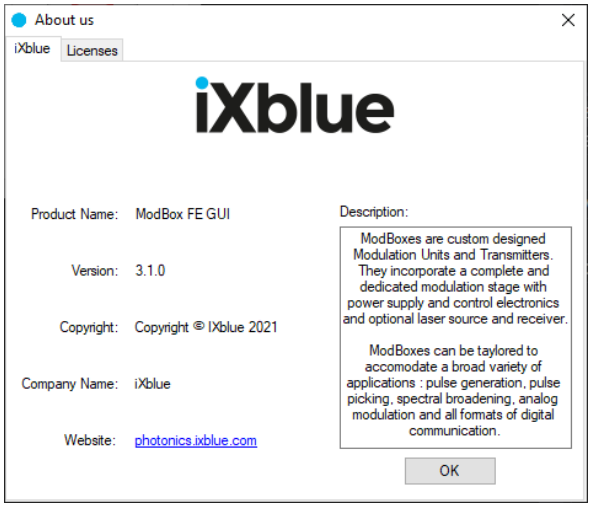


Figure 22: About Dialog

The **Remote Control** item displays a window to configure the remote control server, which can be used to develop your own application:

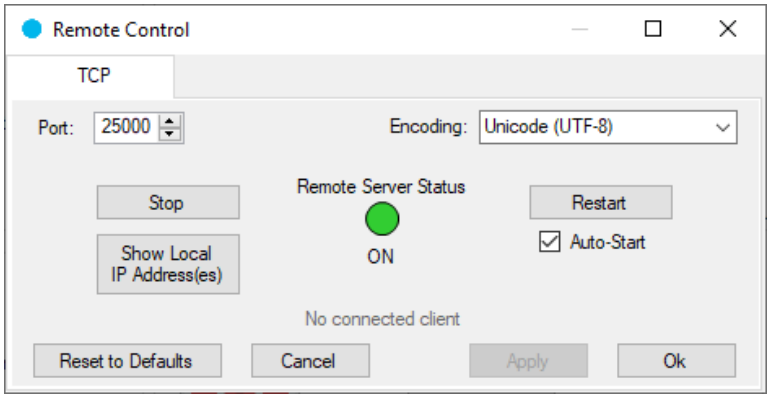


Figure 23: Remote Control Dialog

For more information, please consult the provided ModBox's Remote Control document.

exail CONTACT - SUPPORT

For support:

- by email: contact.photonics@exail.com
- using the form on the exail Photonics web site https://photonics.exail.com/

exail CONTACT - SALES

North America / NORAM

- +1 508 975 4640
  Yves DEISS
  North American Sales Manager
  Cell: +1 (508) 745 3487
  11 Erie Drive
  Natick, MA 01760 - USA
  yves.deiss@exail.com

Europe Middle-East Africa Latin-America / EMEA-LATAM

- +33 1 30 08 88 88
  Hervé Gouraud
  Sales and Marketing Manager
  Phone : +33 3 81 85 31 86
  3, rue Sophie Germain, TEMIS
  F-25000 Besançon, France
  herve.gouraud@exail.com

Asia Pacific / APAC

- +65 6747 4912
  Shuo ZHANG
  China Sales Manager
  Cell: +86 17702287025
  Skype: uperzs
  Wechat: superzs80
  Suite 2039, Qing Yun Modern Plaza
  43 Bei San Huan Xi Road, Haidian Dist,
  Beijing 100086, China
  shuo.zhang@exail.com

Appendices

A MACH-ZEHNDER INTENSITY MODULATORS

Lithium niobate (LiN_bO_3) Mach-Zehnder Modulators (MZM) are external modulator that have been widely used since the mid-nineties, mostly in long haul optical networks for their ability to modulate optical signal from 1300 and 1550 nm laser diodes with short transition times and without chirp compared to direly modulated diode lasers. Thanks to their broad wavelength performance, they currently also offer modulation solutions in the NIR band, and for even shorter wavelengths.

MZM are 2-waves interferometer devices that exhibit a sine transfer function (Fig.13). Although MZMs are highly stable components, their operating point suffers from slow drifts due to variations of external conditions (mechanical strengths, temperature, radiation …). Those drifts may induce key performances time fluctuations (extinction ratio for example).

In order to adjust MZM operating point independently from the applied RF modulating signal, we could use a RF design based on 2 sets of electrodes: the RF set (the RF electrodes) is used to apply the RF signal (PRBS data stream, analog signal, short pulses). The DC electrodes are used to set the modulator's operating set point. Fig.14 illustrates the typical electrode architecture of LiN_bO_3 MZM.

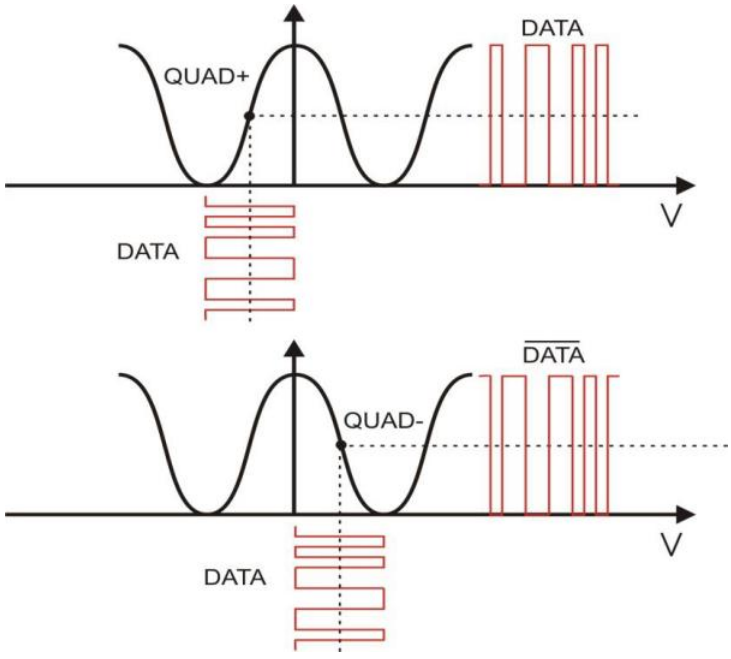


Figure 24: MZM transfer function and data output vs data input at QUAD+ and QUAD- operating point

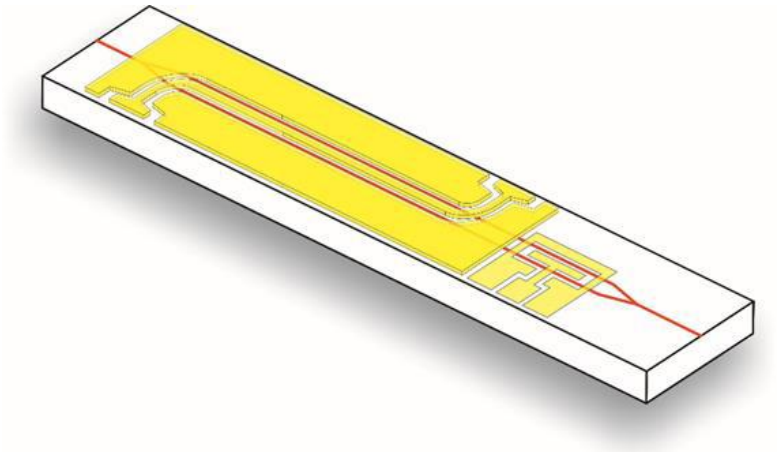


Figure 25: Typical electrode and waveguide architecture of a MZM

B DRIFT EFFECTS

DC drift is the optical output power variation under the constant DC bias voltage application. Fig.15 shows the output power of the modulator as a function of the applied voltage. The broken line shows the output power as a function of applied voltage when only AC voltage is applied (and no DC is applied, at t=0) and the solid line shows the same, after t = t1, when DC voltage is also applied in addition to the previous AC signal voltage. The shift between these two curves: ΔV is the measure of the DC drift.

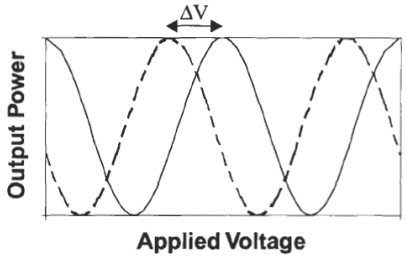


Figure 26: MZM output power vs driving voltage w and w/o DC voltage

The DC drift physical mechanism and its root causes are not yet very well understood. But this can be attributed to the ions movement, including OH- ions, inside the Lithium Niobate substrate and the buffer layer. It is influenced by the balance of the RC time constants in both horizontal and vertical directions in the equivalent circuit model as is displayed in fig.16. It was also reported that the DC drift is more affected by the buffer layer. In the circuit model of fig.16, all layers, including the LIN_bO_3 substrate, the Ti: LiN_bO_3 optical waveguide and the buffer layer are represented in terms of resistances R and capacitances C, in both the vertical and horizontal directions of the crystal.

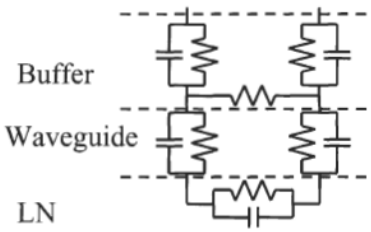


Figure 27: RC equivalent circuit model of the MZM with vertical and horizontal components

Thermal or humidity drift stands for optical output power fluctuations induced by thermal or humidity variations. Local temperature variations induce pyroelectric charge growth inside the LiNbO3 crystal. These charges migrate to the outermost surfaces of the crystal and between the electrodes, thus leading to a charge growth across the arms of the interferometer. This results on a modified electric field seen by the crystal. This then shifts the sinusoidal transfer curve as seen on fig.15, this thermal drift is then very similar in terms of the physics consequences to the drift seen when applying a DC voltage on the DC electrodes. One direction to mitigate this charge accumulation on the crystal surfaces is to use elements meant at dissipating those charges.