PPL 400

Nanosecond Diode Laser with Programmable Pulse Shaping

PicoQuant

User Manual

Document version 1.0.0

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1. Introduction

The PPL 400 is a stand-alone diode laser system for generating nanosecond pulses with programmable shapes and widths ranging from 1 - 330 ns. The mainframe of the system includes an integrated power supply, an oscillator module (SOM 828-D), a voltage controlled laser module (VCL 828), and either one or two dual channel waveform generator modules (SWM 828). The VCL 400 features a polarization maintaining fiber output. The PPL 400 is controlled via an intuitive and easy-to-use PC software package that allows to flexibly design specific waveforms. Pulse shapes can be synthesized from combinations of square and sawtooth forms.

1.1. Oscillator Module (SOM 828-D)

The oscillator module SOM 828-D offers the user unparallelled flexibility in generating trigger pulse sequences for up to 8 output channels. The concept for a coordinated firing sequence is to synthesize triggering signals for each output channel in one central oscillator module. The repetition frequency is derived either from 3 user-selectable crystal stabilized oscillators or from an external input signal. Lower repetition frequencies are realized by a prescaler stage that may be configured for any integer dividing ratio ranging from 1 to 255 for the SOM 828-D oscillator module.

The resulting main clock signal can be distributed to each of the output channels in several ways. Basically, the channels will fire one after the other in a rotating manner. It is possible to group channels to form synchronized pulse patterns or to introduce delays. Furthermore, any number from one to 16.7 million pulses can be output as a burst from one output channel before the next one gets activated. Finally, a “single sweep mode” can be implemented so that the sequencer stops after a full period, waiting for an external signal to be re-triggered.

1.2. Waveform Generator Module (SWM 828)

The waveform generator modules are triggered by the SOM 828-D module and allow to freely select the parameters of a sub-pulse structure consisting of flat top and sawtooth elements. Each waveform generator has two channels and a channel can generate a flat top and / or a sawtooth element. The voltage amplitudes of these elements are added to obtain a specific pulse form. The desired time base of 33, 100, or 330 ns can be selected independently for each generator and determines the duration over which the pulse structure can be defined. Within this time base, the amplitude of the pulse can range from 0 to +1 V while the slope of sawtooth structures varies from 0 to 20 V/µs. These parameters can be varied together with the duration and position of the temporal structure within the limits of the time base. The PPL 400 mainframe has the option of integrating one or two SWM 800 modules, allowing for a total pulse shape synthesis from either 1 x 2 or 2 x 2 channels. Within a continuous pulse sequence, the system can operate at repetition rates from 167 mHz (1 per minute) to 1 MHz and in burst mode from 196 kHz to 1 MHz with a burst rate of 167 mHz (1 per minute) to 500 kHz.

1.3. Voltage Controlled Laser Module (VCL 828)

The laser module is driven by the output of the SWM 828 waveform generator and translates the voltage modulated signal pulses of a particular sequence with its repetition rate into the equivalent optical pulse pattern at the laser diode. The predefined signal of 0 to +1 V obtained from the SWM 828 module is converted into an optical pulse with a central wavelength of 1030, 1064, or 1530 nm with an intensity depending on the used laser diode ranging from 0 to 300 mW after coupling into a polarization preserving single mode fiber. The VCL 828 module is engineered to maintain nearly perfect linearity when translating the modulated analog voltage signal of the SWM 828 to the pulse forms emitted by the laser diode.

1.4. Software Package

The software package included with the PPL 400 system allows configuring and controlling the timing and pulse shapes supplied by the oscillator module SOM 828-D and the waveform generator(s) SWM 400 to the voltage controlled laser module VCL 828 through a host computer. The software runs on the Windows™ operating systems 7, 8 / 8.1, or 10. The PPL 400 is connected to the computer by a USB interface. The pulse parameters that are used for constructing a desired pulse form are translated directly to a graphical representation in the control window. This allows for fast and intuitive construction of various pulse structures at selected repetition and burst rates.

2. Safety Related Instructions

2.1. General Safety Instructions

LASER Warning!

The PPL 400 laser driver comes equipped with a laser diode emitting near infrared (NIR) laser radiation of Class 3B / IIIb. Near infrared light is not visible for the eye!

The following Table 2 summarizes the central emission wavelength, maximum optical output power, and laser class ratings for the different laser diodes that can be commonly installed in the VCL 828 laser module of the PPL 400.

Table 1. Central emission wavelength, maximum optical output power, and laser class rating for the different laser diodes commonly present in the PPL 400.

Central emission wavelength	Maximum optical output power	Laser class rating
1030 nm	300 mW	Class 3B / IIIb
1064 nm	300 mW	Class 3B / IIIb
1530 nm	100 mW	Class 3B / IIIb

When using lasers with class 3B / IIIb, it is required to wear special eye protection (laser safety goggles).

The room in which the PPL 400 is installed must be labeled as laser area.

Lasers can be hazardous and have unique safety requirements. Permanent eye injury and blindness is possible if lasers are used incorrectly. Pay close attention to each safety REMARK and WARNING statement in the user manual. Read all instructions carefully BEFORE operating this device.

Required Laser Safety Measures

Please observe the laser safety measures for laser class 3B / IIIb in accordance with applicable national and federal regulations. The owner / operator is responsible for observing the laser safety regulations.

What does the owner / operator have to observe?

- The owner / operator of this product is responsible for proper and safe operation as well as for the safe maintenance of the system and for following all applicable safety regulations.
- The owner / operator is fully liable for all consequences resulting from the use of the system for any purposes other than those listed in the operating manual. The laser may be operated only by persons who have been instructed in the use of the system and the potential hazards of laser radiation.
- The owner / operator is responsible for performing and monitoring suitable safety measures (according to IEC/EN 60825-1 and the corresponding national regulations).
- The owner / operator is also responsible for naming a laser safety officer or a laser protection adviser (according to the standard IEC/EN 60825-1: "Safety of laser products, Part 1: Classification of systems, requirements and user guidelines" and the respective national regulations).

General Safety Instructions for Operation

- Never look directly into a laser beam or a reflection of the laser beam (specular or diffuse). Avoid all contact with the laser beam.
- Do not introduce any reflective objects into the laser beam path.
- Every person involved with the installation and maintenance of this device has to:
    - Be qualified
    - Follow the instructions of this manual
- As it is impossible to anticipate every potential hazard, please be careful and apply common sense when operating the PPL 400 laser driver. Observe all safety precautions relevant to Class 3B / IIIb lasers.
- Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.
- **Do not open the device** under any circumstances! There are no user serviceable parts inside.
- Never connect or disconnect an optical fiber during operation!

2.2. Safety Label on the Laser Device

The laser warning logo and aperture label, as shown in fig. 1, are visible on the front panel of the VCL 828. The warning logo is located above the laser output port (fiber coupler), while the aperture label is below it (see also fig. 19). An additional laser warning logo is also located to the left of the laser key switch on the SCM 828 front panel (see fig. 3).

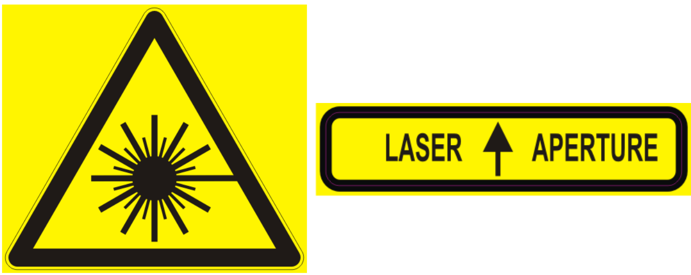

Fig. 1: Laser warning logo and aperture label located on the front

The identification label, located on the back side of the device, left of the main power switch, includes all relevant information such as the model name, serial number, PicoQuant logo, WEEE symbol and CE symbol. The warning and classification label, as show in fig. 2, is located to the left of the identification label.

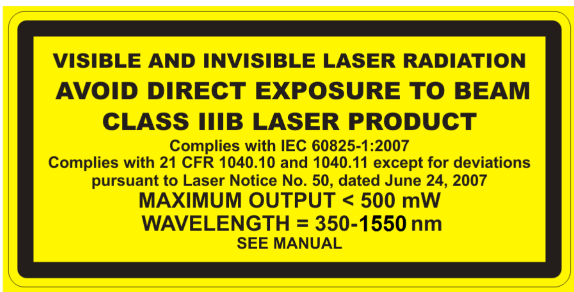

Fig. 2: Laser certification and classification label on the back panel.

2.3. Remote Interlock Connectors

In order to meet laser safety regulations, you may need to install a remote interlock, e. g., a door switch, to deactivate the power to the laser when the door to the laser area is opened. The PPL400 laser driver is delivered by default with an interlock bridge bypassing the connectors. Removing the connector or breaking the interlock circuit will immediately deactivate the power supply of the laser.

The remote interlock connector is located on the front panel of the PPL 400, just below the laser key switch, as shown in fig. 3.

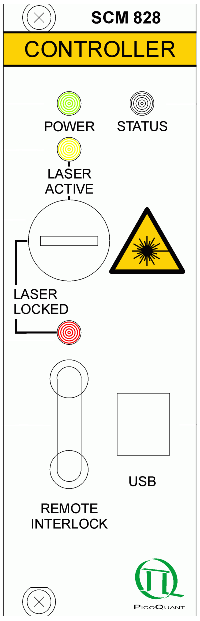

Fig. 3: Remote interlock connectors with interlock bridge

Make sure to follow all safety regulations.

Never plug, unplug or move the output connector of the delivery fiber while the laser is active.

3. Installation and Quick Start

This section contains information for the installation of the hardware and software of the device as well as a non-exhaustive quick start guide. A detailed description of all hardware elements is given in Chapter 4, Hardware Description.

3.1. Hardware Configuration

3.1.1. PPL 400 Mainframe

When placing the PPL 400 mainframe, please ensure a sufficient air flow from the fan at the rear panel by keeping a distance of 10 cm from any obstacle. Do not cover the cooling fan at the rear panel or the venting slots at the bottom of the rack. Leave at least 5 cm of free space under the rack if you mount it into a 19"-cabinet.

Environmental conditions: +10 - +35 °C, relative humidity 20 % – 80 %.

Power Input 100 – 240 V, 50/60 Hz AC, Power consumption < 250 W

The functions of the PPL 400 are controlled from a PC via a USB 2.0 connection. Standalone operation is supported, but changing control parameters requires access to the computer interface.

Before connecting any cables or fibers, make sure that the Main Power Switch at the rear panel is in the OFF position.

Please read and follow all instructions given in Chapter 2, Safety Related Instructions, before switching the PPL 400 on. Also, ensure that the laser key switch is in the secure “LASER LOCKED” position (horizontal)!

Remote Interlock

In order to meet laser safety regulations, it might be necessary to install a remote interlock, e.g., a door switch, to deactivate power to the laser when the door to the laser area is opened. Remote interlock connectors are provided for this purpose.

- Remove the interlock bridge at the SCM 828 front panel and connect the two terminals to the door switch. Common “banana plugs” can be used for the connection. The loop resistance of the cabling including the switch must be less than 10 Ohms. The voltage that is present on this connector is less than 7 V DC.
- When the door switch is open, laser emission is disabled.

Heat Dissipation

Ensure free air circulation. Do not cover the cooling fan on the rear panel or the venting slots at the bottom of the rack.

Connecting the PPL 400 Mainframe

The following guide will assume that a pre-configured system is present, where the controller (SCM 828), oscillator (SOM 828-D), the waveform generator (SWM 828), and the laser (VCL 828) modules are already mounted in their respective slots of the PPL 400 mainframe. In this case, the only connections that need to be made are for power, interfacing with the host computer, and with the optional external synchronization source.

Begin by connecting the main power cord to the socket at the rear of the mainframe. Make sure that the appropriate voltage and frequency of 100 – 240 V, 50/60 Hz AC is provided. Connect the PPL 400 to the host PC via the USB cable and install the laser driver software (see Chapter 3.2).

3.1.2. Controller Module SCM 828

The controller module SCM 828 is installed in the left most slot of the PPL 400 mainframe. It features a series of status indicators, the laser key switch used for locking or activating the laser diode, the remote interlock connector, and the USB interface allowing communication with the host computer. Refer to Chapter 3.2 on how to instal the laser driver software package.

Please note that, prior to powering up the PLL 400, the laser key switch should be in the “LASER LOCKED” (horizontal) position for laser safety reasons.

3.1.3. Oscillator Module SOM 828-D

The SOM 828-D oscillator module is installed in the first slot to the right of the controller module SCM 828. The main purpose of the oscillator module is to provide customizable trigger pulse patterns for the waveform generator modules SWM 828. Thanks to it 8 burst channel sequencer firing in a cyclic patter and versatile software controls, the SOM 828-D offers great flexibility in designing such trigger patterns, allowing for example to synchronize or introduce delays between output channels.

Connection to SWM 828 waveform generator modules is realized by using the coaxial patch cables that are delivered with the PPL 400. The outputs labeled 1..8 on the oscillator module are dedicated to trigger the waveform generators. Connect the trigger input of each generator module (SWM 828) to one of the outputs on the SOM 828-D.

3.1.4. Waveform Generator Module SWM 828

The PPL 400 mainframe can be equipped with either one or two waveform generator modules (SWM 828). These are installed immediately to the right of the oscillator module SOM 828-D. Each waveform generator module features a NIM trigger input into which the pulse patterns stemming from the oscillator module SOM 828-D are fed. The SWM 828 have furthermore an output port where the voltage modulated pulse shape is passed to the laser module as well as an additional control output for an auxiliary fiber amplifier system.

The trigger input port of each SWM 828 module should be connected to one of the eight output channels of the oscillator module SOM 828-D with the supplied coaxial patch cables. The signal output port of each SWM 828 module has be connected one of the signal input ports on the voltage controlled laser module VCL 828 via the standard SMA cables supplied with the PPL 400 laser driver.

3.1.5. Voltage Controlled Laser Module VCL 828

The voltage controlled laser module VCL 828 can be found immediately to the right of the waveform generator module(s) in the PPL 400 mainframe. The module hosts two SMA input ports accepting the voltage modulated signal from the SWM 828 module(s) as well as a fiber coupler serving as laser emission aperture.

The signal input ports of VCL 828 module have to be connected to the output ports of the waveform generator module(s) via the provided SMA cables. An attenuator can be inserted between the SMA cable and the signal input port of the laser module if necessary.

The VCL 828 unit comes with an FC/APC mating sleeve on its front panel. Keep the fiber end clean. Cover the mating sleeve with a cap if the outer fiber is disconnected from the front panel. Clean the delivery fiber FC/APC connector before inserting it into the mating sleeve.

3.2. Software Installation

The PPL 400 should not be turned on before the control software is installed on the host computer!

Before installing and using the PPL 400, please make sure to have

1. a solid base onto which the PPL 400 can be placed (e.g., an optical table)
2. a computer to install and run the operation software. The computer needs to have a free USB slot as well as a supported Windows operating system (7, 8 / 8.1, or 10).

Place the PPL 400 on its dedicated place, plug the power cord and connect the PPL 400 to the host computer using the delivered USB cable.

The control software "**`PQLaserDrv.exe`**" for your PPL 400 and other laser drivers manufactured by PicoQuant needs to be set-up by an installer and is supplied on the CD along with your device. Installing the software is straightforward and performed by a step-by-step installation wizard. To install the software:

1. Insert the CD into the host computer.
2. Launch the program: `PQLaserDrv_Setup.exe`
3. Follow the instructions on the screen:

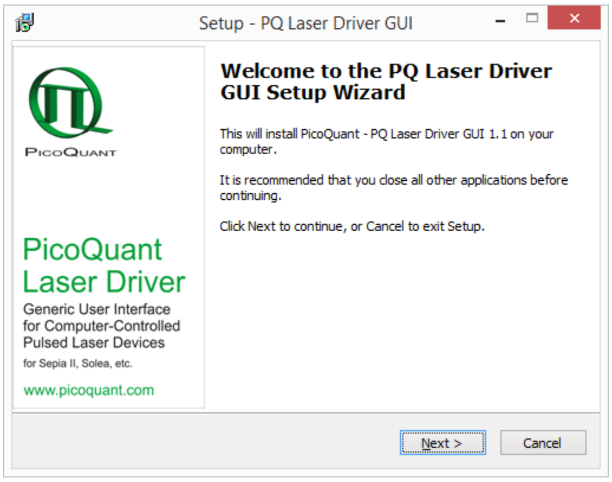

Fig. 5: PQ Laser Driver GUI Setup Wizard - Welcome window

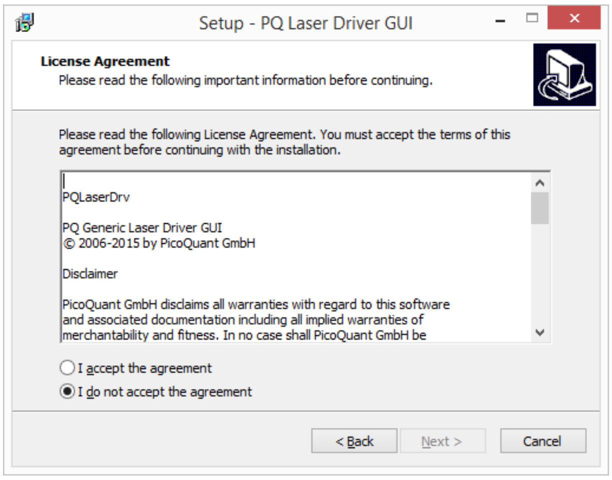

Fig. 4: PQ Laser Driver GUI Setup Wizard - License Agreement

Accept the License agreement and click *Next* when requested (See fig. 5, 4, and 7).

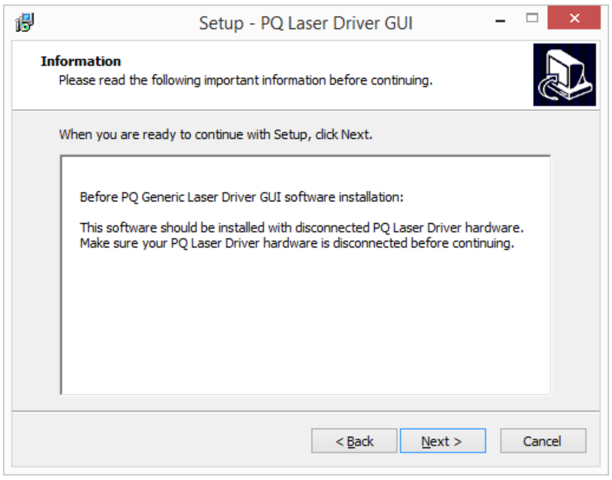

Fig. 7: PQ Laser Driver GUI Setup Wizard - Warning

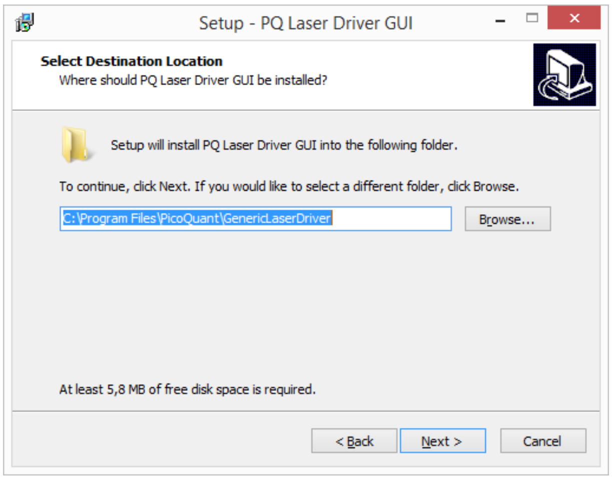

Fig. 6: PQ Laser Driver GUI Setup Wizard – Select destination

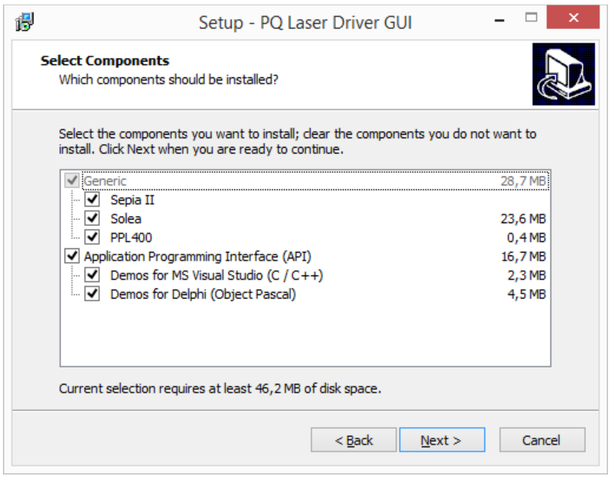

Fig. 8: PQ Laser Driver GUI Setup Wizard - Define devices

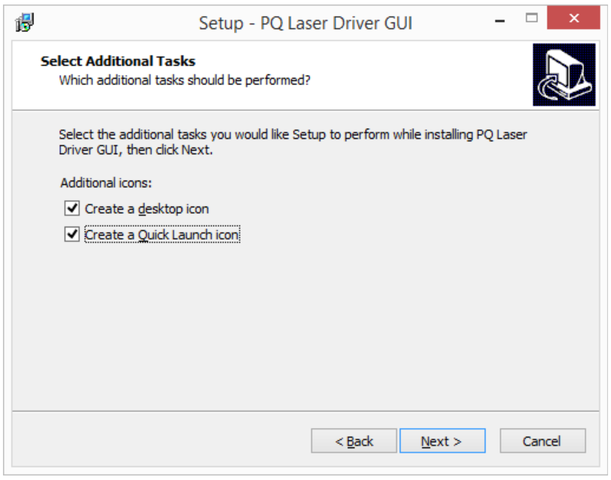

Fig. 9: PQ Laser Driver GUI Setup Wizard - Launch icon

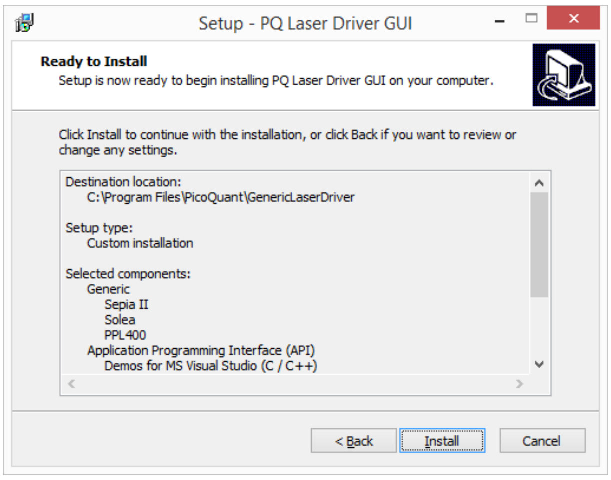

Fig. 10: PQ Laser Driver GUI Setup Wizard - Start installation

Define the destination folder for the installation of the software (fig. 6), the components to be installed (Solea, Sepia II, PPL 400, or any combination of these; fig. 8), and which launcher icons that should be generated (fig. 9). Click *Next* to validate your choices and then the *Install* button to start the installation as shown in fig. 10.

Important Remarks:

The PicoQuant Laser Driver Software can control not only the PPL 400 but also the Solea laser from PicoQuant. In case you need to control a PPL 400, PDL 828 “Sepia II”, and a Solea laser, then it is necessary to install all components (see fig. 8).

It is recommended to choose at least one of the suggested icon options (see fig. 9). For each icon option chosen, the installer automatically creates two software launchers corresponding to the “Bright” and “Dark” PicoQuant color themes. For more details about the software color themes please refer to Chapter 5.

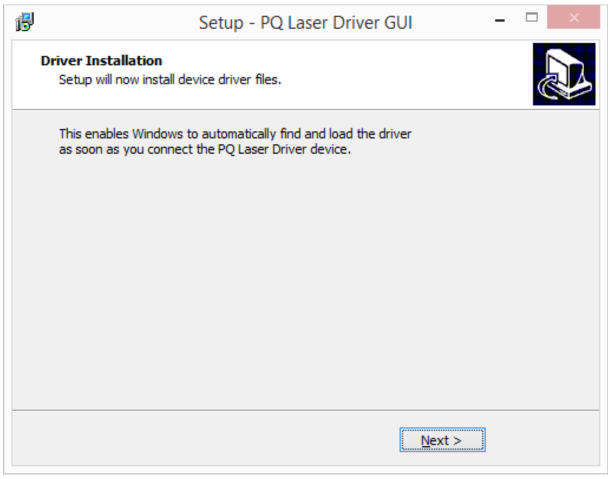

Fig. 11: PQ Laser Driver GUI Setup Wizard - Driver installation

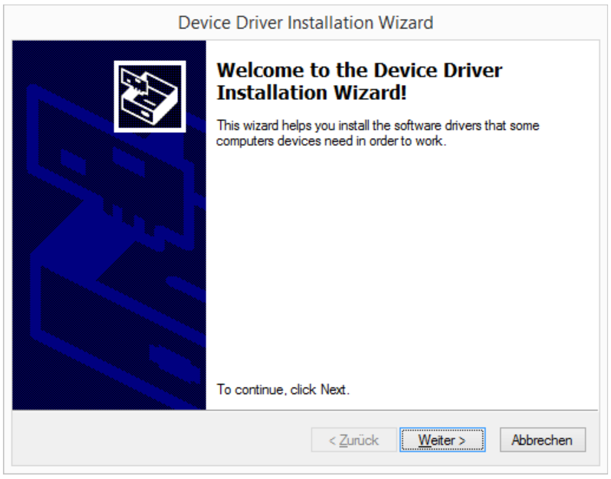

Fig. 12: PQ Laser Driver GUI Setup Wizard - Driver installation

Click *Next* to start the installation of the drivers as shown in fig. 11 and fig. 12.

It is possible that a *Windows Safety Warning* windows pops up. In that case confirm the installation when requested in order to continue with the installation.

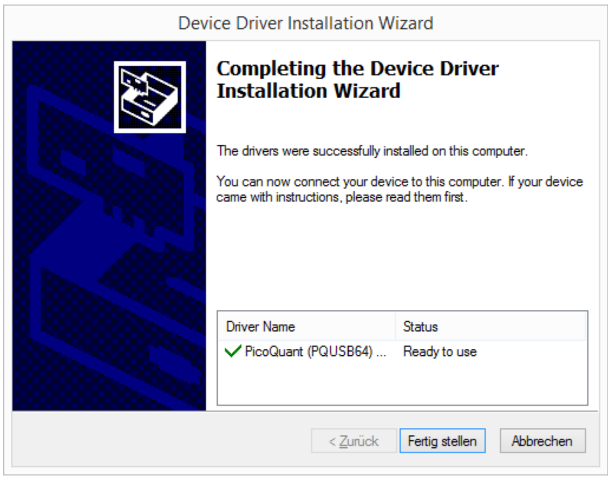

Fig. 13: PQ Laser Driver GUI Setup Wizard - Driver completed

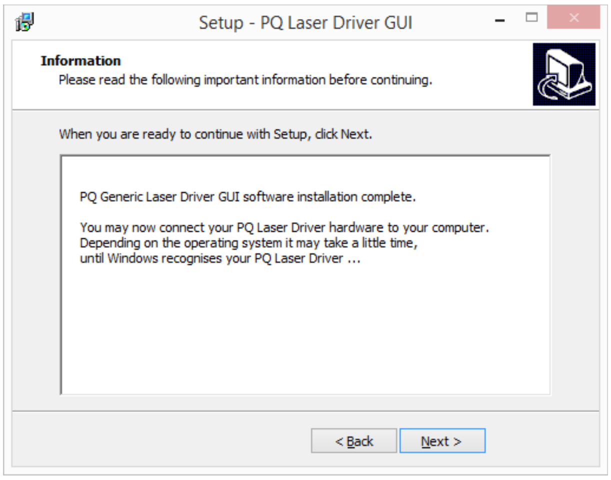

Fig. 14: PQ Laser Driver GUI Setup Wizard - Setup completed

Click *Next* when requested to complete the installation as shown in fig. 13 and fig. 14.

Click *Finish* to close the Installation wizard (fig. 15).

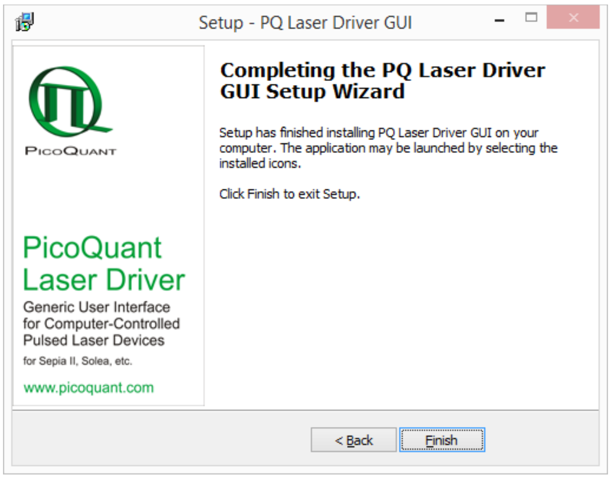

Fig. 15: PQ Laser Driver GUI Setup Wizard - Finish

Once the software is installed, the PPL 400 can be turned on (see Chapter 3.3). When the laser is turned on for the first time, Windows will detect a new device and install the necessary device drivers.

3.3. Quick Start Guide

The follow sequence constitutes the standard procedure for starting the PPL 400 laser driver:

Before turning the PPL 400 on, read and follow the instructions given in Chapter 2, Safety Related Instructions. Also, ensure that the laser key switch is in the secure “LASER LOCKED” position (horizontal)!

1. Switch on the main power on via the main switch at the back of the mainframe.
    - The “POWER” LED on the SCM 828 module will turn on and emit continuous green light.
    - The “STATUS” LED on the SCM 828 module will first blink red and then green as the system powers up. A continuous green light shows that the system is ready for operation.
    - The “LASER LOCKED” LED on the SCM 828 module will be continuously emit red light when the laser key switch is in the horizontal position (i.e. LASER LOCKED position). Laser emission will be disabled when the key is in this position.
    - The “MODE” LED on the SOM 828-D module will stay dark during the power up sequence.
    - The “STATUS” LED on the SWM 828 modules shows up as red while the system is powering up and then switches to green to signal that modules are ready.
    - The “STATUS” LED on the VCL module is off, showing that there is no emission from the laser. The other two LEDs will light up in green if the laser diode temperature is either above or below the set-point temperature, respectively, and requires time to regulate it. When the diode is at the set-point temperature, both LEDs will be dark.
2. Start the controller software on the host computer once the “STATUS” LED on the SCM 828 module shows constant green light.
    - The main GUI panel of the PPL 400 system will appear, including control panels for all modules present in the mainframe (refer to fig. 20 in Chapter 5).

NOTE:	**Carrying out the actions in points 3 to 8 is only necessary if you need to configure the pulse sequence, repetition rate, and to generate specific pulse shapes. These tasks can be omitted if the system should start up with the original factory settings or if the desired settings have been saved before exiting the software in the previous session.**

3. Locate the SOM 828-D control panel in the GUI (second left-most panel).
    - ○ Chose one the three internal oscillators (50, 64, or 80 MHz) and enter the desired value for divider (integer value ranging from 1 to 255) to obtain the base repetition rate. If an external trigger signal should be used, chose the option “*Ext. Trig.*” instead of an internal oscillator and set the divider to obtain the desired repetition rate.
    - ○ Configure the eight possible output channels in order to obtain the desired pulse pattern (see Chapter 5 for detailed instructions). Make sure that the programmed, active output channels of the SOM 828-D oscillator module are connected to the respective TRIG. IN ports of the SWM 828 modules via NIM patch cables.
4. The SWM 828 control panel, located to the right of the SOM 828-D panel, contains a series of parameter allowing to construct the desired pulse shape. This control panel will feature either one or two sets of parameters depending on how many SWM 828 modules are installed in the PPL 400. Each parameter set contains settings for generating two curves composed of either a top hat, a sawtooth or a combination of both profile types. The following parameters can be individually chosen to realize the desired pulse shape: pulse amplitude and start time, ramp slew and start time, as well as wave stop time.
    - See Chapter 5 (Software GUI Description) and 6 (Examples / Modes of Operation) for a detailed description of these parameters and examples in constructing a desired pulse form.

- Parameters changes are automatically transferred to the curve shown in the "*Visualize Curve(s)*" panel as soon as the corresponding edit field loses focus. The panel can be opened by pressing the corresponding button in the SWM 828 control panel.
- Make sure that the amplitude of the constructed pulse shape always lies within the lower limit corresponding the diodes lasing threshold and the upper limit where the laser diode reaches saturation. These limits are shown as dotted lines in the graph.

5. Once the desired pulse pattern (through the SOM 828-D control panel) and shape (through the SWM 828 control panel) have been created, transmit the data to the PPL 400 by clicking on the "*Apply*" button in the lower right part of the GUI. Please note that this may take some time, depending on the amount of changes made to the configuration.
6. In order to activate laser emission, turn the laser key switch on the front panel of the SCM 828 module from the horizontal "LASER LOCKED" to the vertical "LASER ACTIVE" position.
    - On the SCM 828 module, the "LASER ACTIVE" LED above the laser key switch will light up in yellow while the "LASER LOCKED" LED will switch from red to off.
    - On the VCL 828 module, the topmost LED will light up in green, showing that the laser is active and emitting. The two LED below it indicate whether the diode temperature regulation is currently active: the upper LED will be lit when the temperature is being increased, while the lower will switch on when the laser diode is being cooled.
    - The diode laser is now emitting laser light according to the constructed pulse shape, selected repetition rate, and desired pulse sequence.

The standard procedure for shutting down the PPL 400 laser driver is as follows:

1. If desired, save the current device settings in one of the two available preset slots.
2. Turn the laser key switch on the front panel of the SCM 828 module from the vertical "LASER ACTIVE" to the horizontal "LASER LOCKED" position.
    - The topmost indicator LED on the VCL 828 module will switch from green to off, indicating that laser light is no longer emitted.
    - On the SCM 828 module, the "LASER ACTIVE" LED above the laser key switch will be turned off, while the "LASER LOCKED" LED below will light up in red.
3. Turn off the main power by flipping the power switch at the back of the PPL 400 laser driver.
4. Quit the controller program by closing the main GUI window.

4. Hardware Description

4.1. Controller Module SCM 828

4.1.1. Front Panel

The controller module is a fixed component of in the PPL 400 mainframe. It contains a micro-controller that manages all other modules inside the mainframe and processes the communication to the external PC via USB interface.

The front panel includes not only the USB interface but also the laser key switch, the remote interlock and a series of LED indicators (see fig. 16)

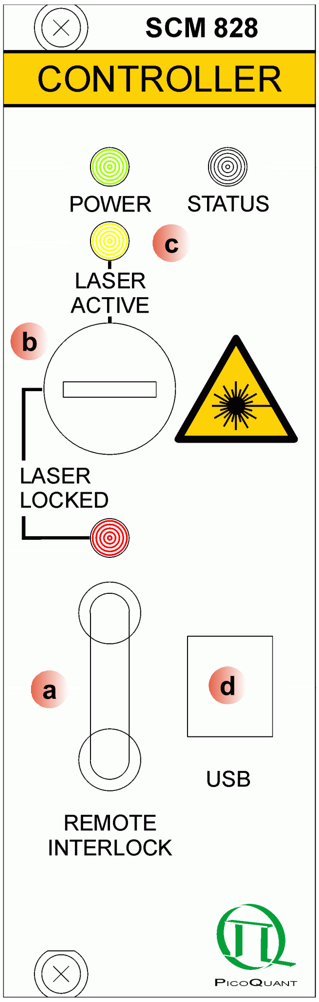

Fig. 16: SCM 828 front panel.

- a **REMOTE INTERLOCK** connector
- b **LASER LOCK** key switch
- c LED indicators*:*
  - **POWER:** green LED. Turns on when the main power is switched on
  - **STATUS**: green / yellow / red LED. A blinking sequence with various colors displays the device status during check-up and operation of the device. See chapter 11.1 for more information.

- **LASER ACTIVE:** yellow LED. Lights up as soon as the voltages to run the drivers are provided by the power supply within their individual limits, applied to the power lines on the back plane of the mainframe, and checked for by the meter circuit of the controller. This indicates that one or several laser heads can be active and that all precautions related to laser safety must be observed. If it turns off while POWER is still green, it indicates most probably a broken fuse or an intolerable adjustment loss in the power supply. If read out via software, this class of errors results in an error code from the -4000er group (-4001 to -4030) indicating too low or too high voltage on the individually indicated power line. See chapter 8.1 for support procedures.
- **LASER LOCKED**: red LED. Turns on when the key switch is turned to the *LASER LOCKED* position (horizontal) or if the controller state is set to “Soft Locked” by the software.

d USB connector to interface the PDL 828 “Sepia II” with the PC

Laser radiation can be emitted when the yellow LASER ACTIVE LED is on. Refer to chapter 2 for laser safety instructions and chapter 3 for information on installation.

Turn the key-switch to LASER LOCKED (horizontal position) in order to disable laser output from all connected laser heads.

Laser Locked

- The key switch interrupts the laser power supply when it is in the horizontal position. The key can be removed only in this position. It's a good practice to keep the key switch locked unless the connected laser heads can be operated according to safety regulations.
- The remote interlock shuts the laser power supply off when the loop current is interrupted.
- To comply to the laser safety regulations, the laser module is locked off for at least the first 10 seconds after the main power has been switched on.
- The controller holds the laser locked off as long as it checks its hardware while powering up.
- The controller keeps the device locked off, if it detects any abnormal operating conditions.
- The controller can be instructed from the GUI or from any software using the programming library (API DLL) to hold the lasers locked off regardless of the position of the key switch. Refer to chapter 5 (GUI) and the separate API manual for more information on soft locking.

Soft locking the lasers does not ensure eye safety!

4.1.2. Controller Operation

At power up, the micro–controller unit performs some basic checks on the module hardware before the rack is ready for operation. Once these tests are successfully completed, the “STATUS” indicator emits constant green light and all modules operate according to their last settings.

If the check fails, the rack may be become blocked and the “STATUS” indicator will show approx. 15 sec. red light alternating with a yellow blink code to identify the slot number where the error was detected. Refer to chapter 11.1 for details on error diagnosis.

4.2. Oscillator Module SOM 828-D

The SOM 828-D oscillator module is a versatile and complex device, providing many options and great freedom for the generation of trigger pulse patterns. Giving a full run-down of its operating principles and capabilities would exceed the scope of this manual. An in-depth presentation of the SOM 828-D oscillator module, along with step-by-step guides on how to configure it, is given in the chapters 4, 5, and 6 of the **PDL 828 “Sepia II” manual**. This manual is automatically installed during the setup of the laser driver software (see chapter 3.2).

The pulse pattern and repetition rate provided by the SOM 828-D oscillator module is used to trigger the SWM 828 waveform generator modules, which will be used to create the desired electrical pulse shape.

4.2.1. Front Panel

The oscillator front panel (fig. 17) includes various connectors for the trigger and auxiliary inputs and outputs as well as a synchronization output port.

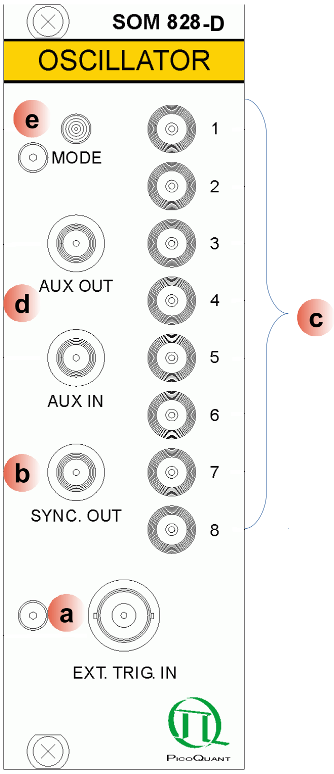

Fig. 17: SOM 828-D front panel

- **a** External trigger input (**EXT. TRIG. IN**)
- **b** Synchronization output (**SYNC. OUT**)
- **c** 8 output channels
- **d** Auxiliary ports:
  - **AUX IN**
  - **AUX OUT**
- **e** Operating **MODE** LED indicator

4.3. Waveform Generator SWM 828

Each SWM 828 module features two generators allowing to produce a curve consisting of a top hat and / or a saw tooth profile element. The parameters of the components can be set individually in the laser driver software GUI, thus allowing to generate a linear combination of both types of shapes. Since the PPL 400 mainframe can host up to two of these modules, one can create a complex, composite pulse shape combining up to four top hat and four saw tooth pulses and any kind of combination of them. The parameters such as amplitude, wave start, ramp slew, ramp start, and wave stop are fully controlled by the laser driver software GUI (see chapter 5).

The pulse shape created by the SWM 828 module(s) together with the trigger information from the SOM 828-D module will be passed on to the laser module VCL 828. There, the voltage profile will be transformed into laser pulses with the desired time-dependent intensity profile and repetition rate.

4.3.1. Front Panel

The SWM 828 front panel (fig. 18) features an input port for the triggering signal of the SOM 828-D oscillator module, a status indicator LED and output ports for both pulse shape and a control signal.

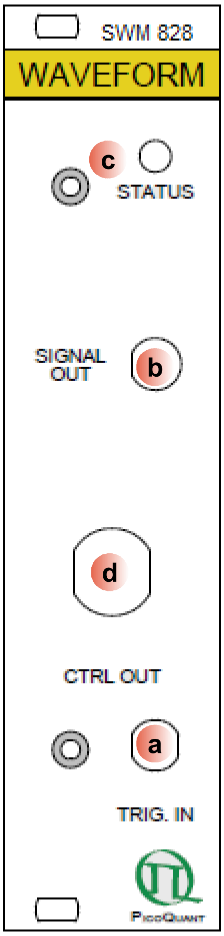

Fig. 18: SWM 828 front panel

- **a** Trigger signal input (**TRIG. IN**); to be connected to the SOM 828-D oscillator module
- **b** Pulse shape signal output (**SIGNAL OUT**); to be connected to the VCL 828 laser module
- **c** **STATUS** indicator LED
- **d** Control output port (**CTRL OUT**)

4.4. Voltage Controlled Laser Module VCL 828

The voltage controlled laser module VCL 828 turns the pulse shape signal of the SWM 828 module(s) into the corresponding voltage modulated laser light output. The optical output power is correlated to the input voltage, starting from the diode specific lasing threshold up to a maximum voltage of 1 V. The voltage value corresponding the lasing threshold of your laser diode can be found in the Laser Delivery Report in the Appendix of this manual.

Each of the two waveform generator channels in a single SWM 828 module can provide an amplitude of up to 1 V. The amplitudes of the two channels is added inside of the SWM 828 before the signal is sent to the output port. The VCL 828 is adding the amplitudes of its two waveform inputs for laser intensity regulation.

When the VCL 828 is connected to only one active SWM 828, the waveform amplitude for laser intensity regulation can reach 2 V. But when the VCL 828 is connected to two active SWM 828, the waveform amplitude for laser intensity regulation can reach 4 V if the four used SWM 828 channels reach their maximum of 1 V at the same time.

Since the upper limit for laser intensity regulation is 1 V, one needs to include attenuators in front of the input channels of the VCL 828 to avoid signal clipping. The needed attenuation can be calculated with the following formula:

$$attenuation = 20 \cdot \log\left(\frac{total\,input\ voltage}{upper\ regulator\ limit}\right)$$

Thus, when using the two channels of one SWM 828 module, the needed attenuation is: 20log(2 / 1) = 6 db. If all channels of two SWM 828 modules are used, the attenuation that has to be used would be 12 db. The attenuators have to be installed between the SWM 828 output and the VCL 828 input ports.

4.4.1. Front Panel

The front panel of the VCL 828 voltage controlled laser module has a fiber coupler unit acting as the laser emission aperture, two input ports, and an indicator LED.

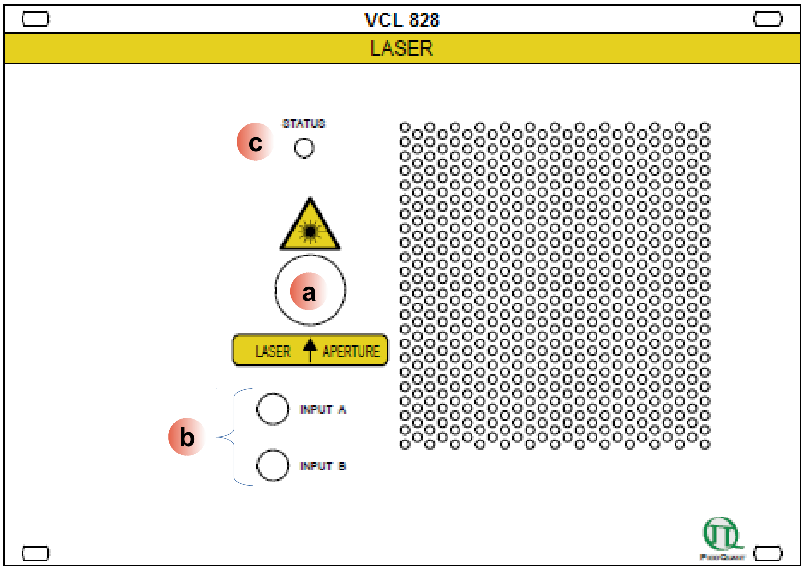

Fig. 19: VCL 828 front panel

- **a** Output fiber coupler
- **b** Input ports (**INPUT A**, **INPUT B**) for the pulse shape signal from the SWM 828 modules
- **c** **STATUS** indicator LED:
  - Turns from off to green when the diode laser is activated via the laser key switch on the SCM 828 control module
  - Flashes green if the center emission wavelength is out of tolerance due to temperature drift or if the diode laser is deactivated to prevent damage (when temperature is much to high)

5. Software GUI Description

5.1. PQLaserDrv – The Graphical User Interface (GUI) for the PPL 400

The PPL 400 must be turned on and the initialization process completed, before the software can be started!

The PPL 400 GUI is available in three different **color schemes:** PicoQuant bright scheme, PicoQuant dark scheme and standard Windows scheme. The latter can be customized using the standard Window control panel.

The dark scheme is intended for light sensitive set-ups and experiments such as, e.g., photon counting and single molecule sensitive spectroscopy set-ups, where ambient light perturbation should be minimized as far as possible. However, for better readability, all screen shots in this manual correspond to the PicoQuant bright color scheme.

The color scheme is applied by the command line parameter "`/style=<scheme>`" where the placeholder `<scheme>` could be one of the legal values "`dark`", "`bright`" or "`windows`".

During the installation setup of the software, the installer can optionally generate separate desktop as well as quick launch icons for the respective bright and dark schemes (see chapter 3.2).

In the interest of ergonomics, all relevant active controls (button, edit box, etc.) change color when the mouse pointer hovers above them.

An overview of the GUI with all control elements is shown in fig. 20 below. The GUI displays only the control elements for the modules that are included in the mainframe and detected during the initialization of the hardware. The example shows the GUI for a PPL 400 mainframe equipped with the controller module SCM, the oscillator module SOM 828-D, two waveform generator modules SWM 828, and a laser module VCL 828.

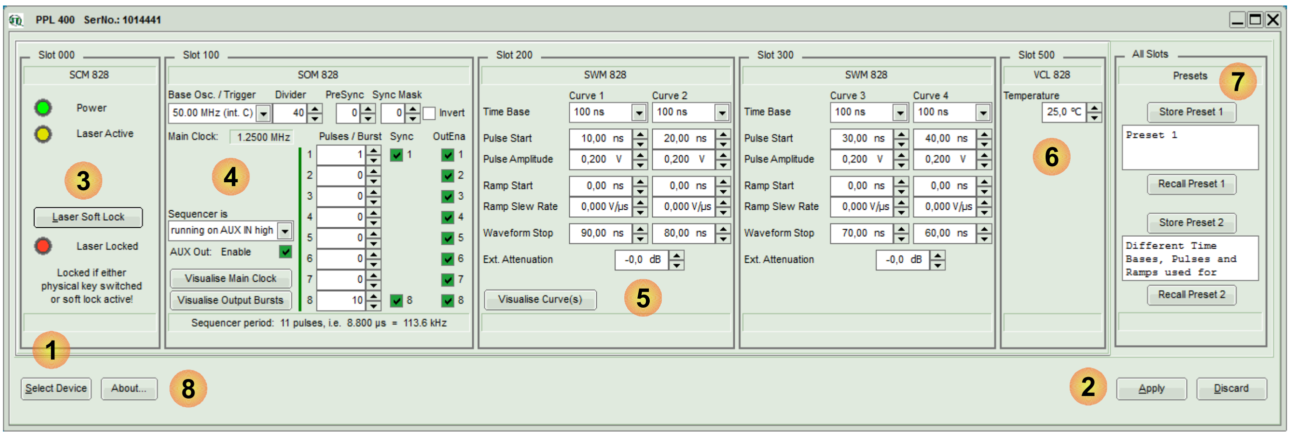

Fig. 20: PPL 400 GUI - overview of all control groups with indication of the individual sections

5.1.1. Select Device 1

The *Select Device* function is useful if more than one PPL 400 (or any other USB laser device from PicoQuant such as a Solea or a PDL 828 "Sepia II") are connected to the same host computer. It can also be used to restore the USB connection to the device should it be lost during operation for any reason.

A mouse click on the *Select Device* button will start a scan for supported devices connected to the PC.

A modal dialogue with an *OK* and *Cancel* button presents a list box with the currently connected devices (fig. 21). When opening the list box, all detected devices are listed by their serial number. The currently selected device is marked with an asterisk "*".

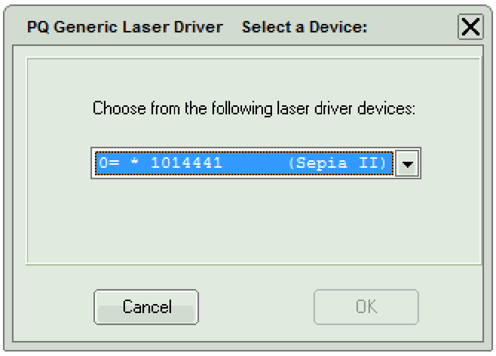

Fig. 21: Select device

Cancel Back to the main window without any changes.

OK Change to the newly selected device. Note that this might lead to changes in the GUI, if a device of different type or configuration is selected. The serial number of the currently selected device is always displayed in the title bar of the software.

5.1.2. Apply / Discard 2

Apply and *Discard* buttons must be used to confirm or discard the configuration changes made in the GUI. In the example shown in fig. 22, changes have been made to the parameters of the oscillator module. The *SOM 828* label and the *Apply* button are therefore highlighted in orange and remain highlighted until the changes are either applied or discarded.

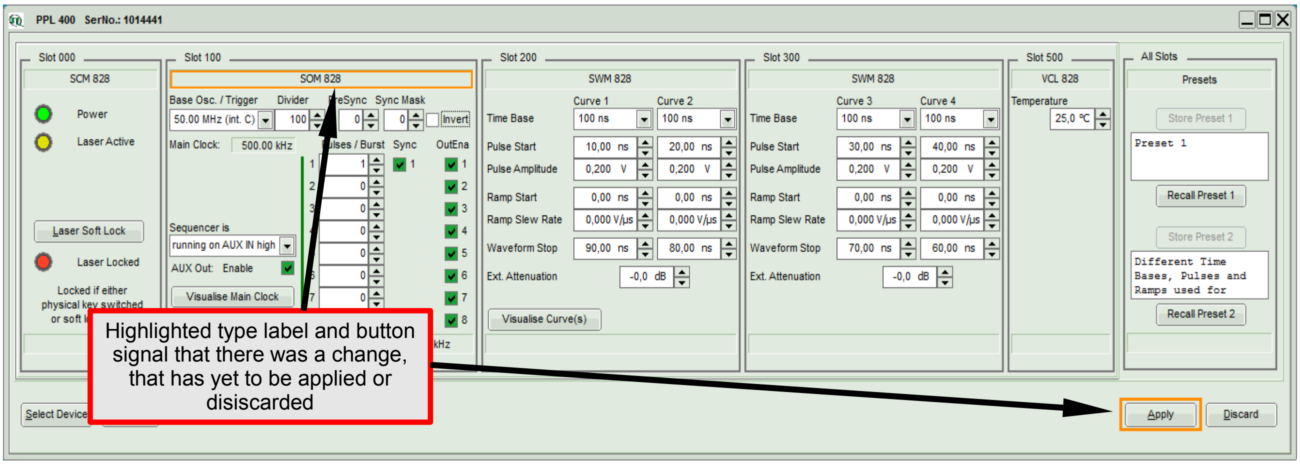

Fig. 22: Elements highlighted in orange indicate a recent change of parameters, which have to be applied or discarded

5.1.3. Soft Lock and Unlock of the PPL 400 3

The PPL 400 can be locked (no laser light emission) and unlocked (laser light is emitted) not only with the hardware laser key switch on the front panel, but also via the GUI by clicking on the button labeled *Laser Soft Lock / Laser Soft Unlock*, which is located in the controller frame on the left side of the software window.

The *Laser Unlocked* state is recognizable in the software by the *Laser Locked* indicator turning dark red (see fig. 23). In addition, the **LASER LOCKED** LED on the front panel of the PDL 828 “Sepia II” has turned OFF.

The *Laser Locked* state is recognizable in the software by the *Laser Locked* indicator turning bright red. The button text could be either *Laser Soft Lock* in case the system was hard locked by key or remote interlock circuit (see fig. 24), or *Laser Soft Unlock* (see fig. 25) in case the system was soft locked (This even masks a hard lock state). In addition, the **LASER LOCKED** LED on the front panel of the PDL 828 “Sepia II” has turned ON.

Please note that the lock state indicated in the GUI may refresh with a slight delay (< 1 s) with respect to the hardware *LASER LOCKED* LED on the front panel of the PPL 400 (see chapter 4.1.1). **Consider:** The soft lock state is not persistently stored in the system. It is lost after power down / power up.

Before unlocking the laser, please refer to chapter 2 Safety Related Instructions. Allow about 3 – 5 minutes warm-up time after unlocking the laser to reach a stable output power.

Fig. 23: Laser unlocked

Fig. 24: Laser hard locked

Fig. 25: Laser soft locked

5.1.4. Oscillator Module SOM 828-D 4

The control element for the SOM 828-D is shown in fig. 26 below:

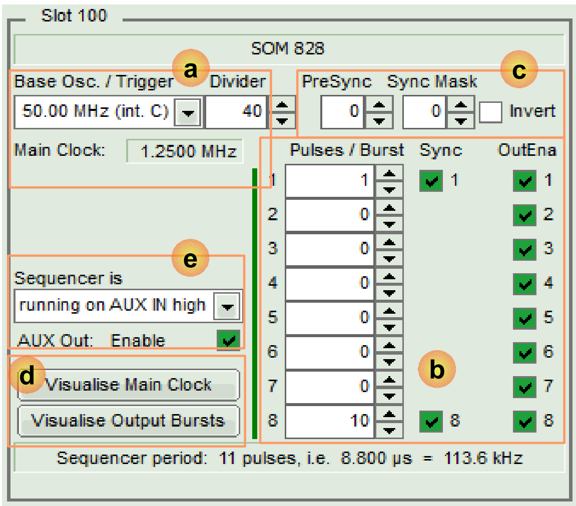

Fig. 26: Control element for the SOM 828-D

a Set Main Clock and Trigger:

The frequency of the *main clock* is derived from the chosen ***base oscillator*** (*80 MHz, 64 MHz, or 50 MHz*) or external ***Trigger*** source (*rising edge* or *falling edge*) and from the dividing factor ***Divider***. Fig. 26 shows an example of *Main Clock* set at 1.25 MHz derived from the internal base oscillator of 50 MHz and a dividing factor of 40.

NOTE !	**It is possible to set repetition rates higher than the maximally specified 1 MHz for the PPL 400. Such a setting will not damage the device. However, running the PPL 400 with a too fast sequencer repetition period (above 1 MHz) will result in timing issues that make it impossible to generate the desired pulse shape.**

NOTE!	**Also, please note that at repetition rates close to the specified maximum, the PPL 400 might not be able to properly generate waveform components with small amplitudes. In such cases, it is recommended to reduce the repetition rate until the desired pulse shape (with the correct signal timing) can be observed on an oscilloscope.**

The *base oscillator* or *trigger* source can be chosen from the drop down menu as shown in fig. 27. The dividing factor set by the spin edit box labeled *Divider* can be set to any integer value between 1 and 65536.

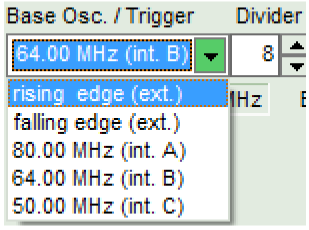

Fig. 27: Setting Main Clock

In case an external *trigger* source (*rising edge* or *falling edge*) is chosen, a spin edit box labeled *Trigger Level* appears where the threshold value can be entered (see fig. 28).

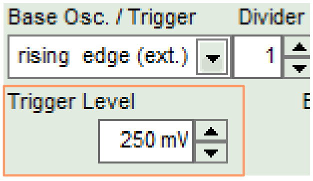

Fig. 28: Setting trigger level

b **Sequencer configuration panel:**

Pulses / Burst: The exact number of pulses per channel can be set by this spin edit box. A burst can consist of any integer number of pulses between 1 and 16.7 millions (16 777 215 pulses).

The text field labeled *Sequencer period* at the control panel bottom summarizes the content of the whole sequencer period (total amount of pulses, sequence period length, and sequence repetition rate). Note that this timing information cannot be displayed when the SOM 828-D is triggered externally.

Sync: The generation of a synchronization pulse at the synchronization output (fig. 17, items marked **b**) can be *enabled* or *disabled* through the corresponding check box.

***Enable**:* The output signals of each channel can be *enabled* or *disabled* at the respective **output channels** (fig. 17, items marked **c**) through the corresponding check box. Each of the 8 channels can be disabled without influencing the sequencer period or any other channel. A disabled channel will not output any electrical signal, but will still “count” its pulses.

c **Define sync signal by PreSync, Sync Mask and Invert:**

PreSync: This setting is used for selecting a digital timing offset between the synchronization pulse and corresponding signal output. Pulses at the **Sync Out** port are emitted before the signal at the trigger output. This offset is selectable in steps of one period of the chosen base frequency. The amount of periods can be any integer from zero up to the value of *divider factor-1*.

Sync Mask: This setting is used to disable the generation of the **Sync Out** signal (but not the signal at the output channels). The value given defines the number of synchronization pulses that are omitted at the beginning of a burst. The number of pulses that can be masked can be selected between 0 and 255 pulses.

Invert: the invert function can be activated by a check box. It is used to invert the effect of the Sync Masking, i.e. the settings specify the number of synchronization pulses emitted at the beginning of a burst.

d **Visualise Main Clock and Visualise Output Burst:**

The **Visualise Main Clock** button brings up a visualization window that shows a time based representation of the base oscillator, the main clock, and the synchronization output (unmasked).

Visualise Output Bursts brings up a visualization window that shows a time based representation of the main clock, bursts and synchronization output (masked, but Pre Sync shift ignored).

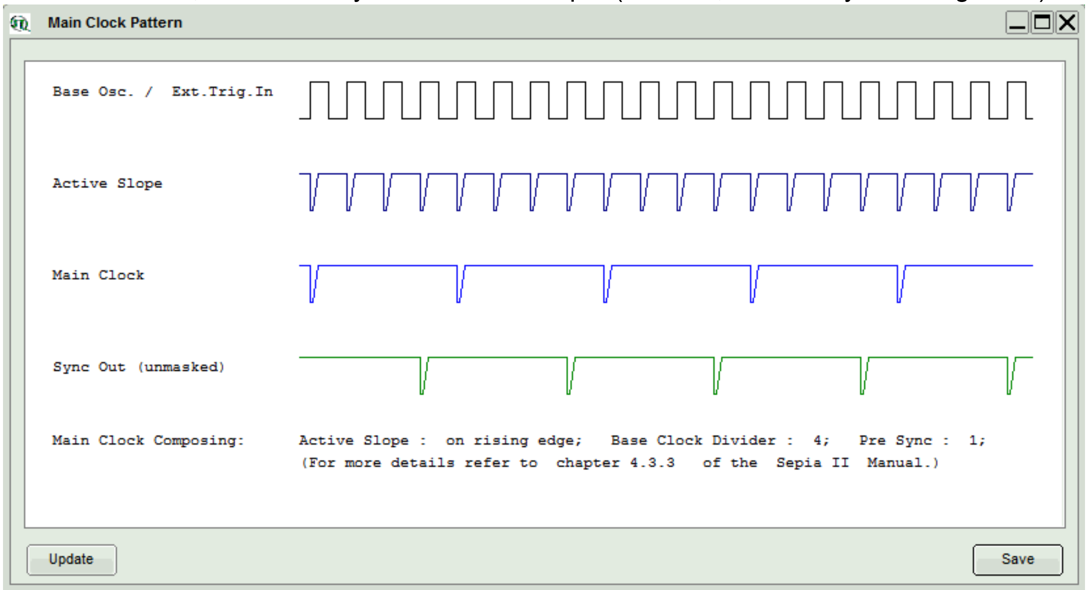

Fig. 29: Visualization of the Main Clock as set in fig. 26

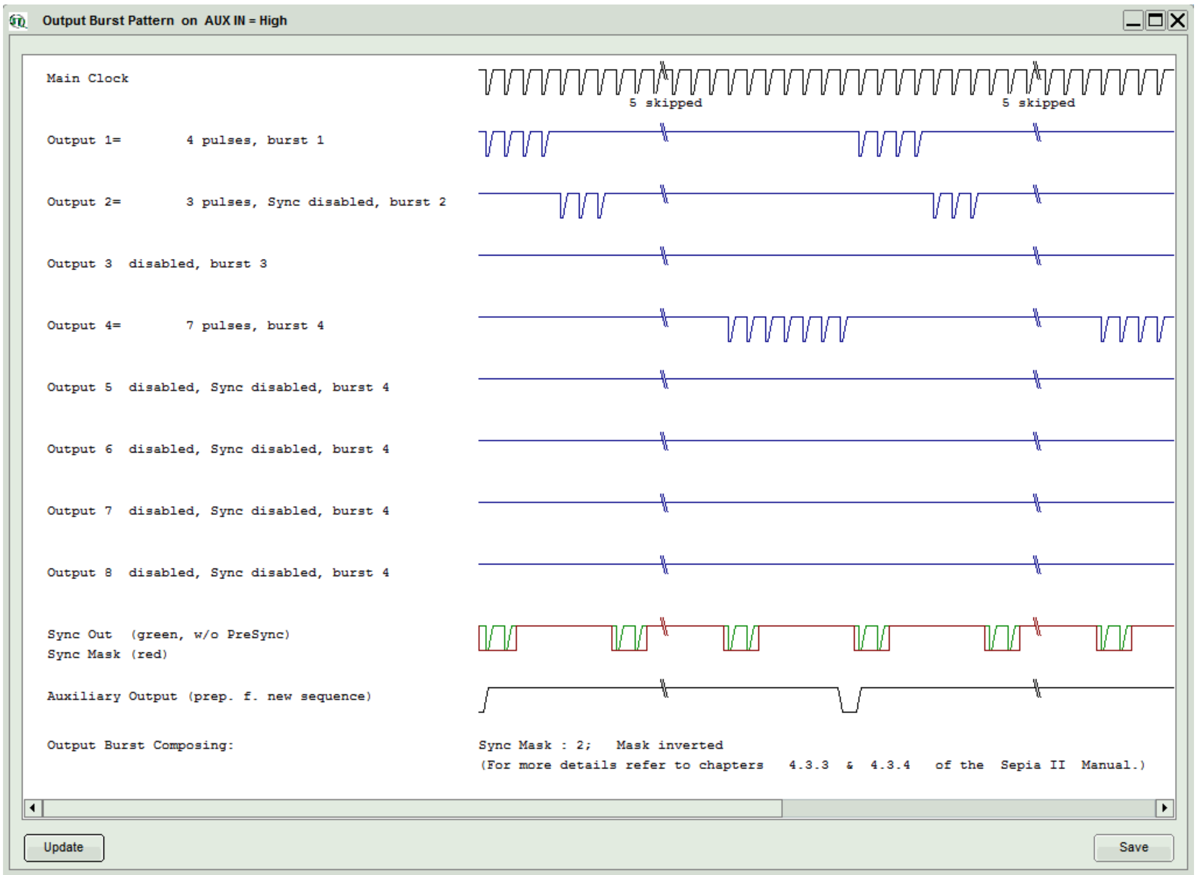

Fig. 30: Visualization of the output bursts as set in fig. 26.

e **Set Auxiliary Input / Output:**

The auxiliary input can be used in order to disable or enable the sequencer of the oscillator module. The running / restarting condition of the sequencer can be controlled by the sequencer mode selected here and if chosen the signal level applied to AUX IN, as shown in fig. 31.

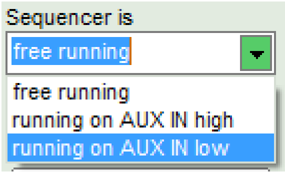

Fig. 31: AUX In: Running states

The auxiliary output can deliver a trigger signal at the end of a SOM 828-D sequence. The generation of the *AUX Out* trigger signal can be simply activated/deactivated by a check box as shown in fig. 32.

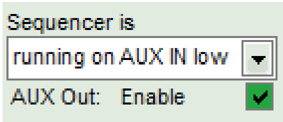

Fig. 32: AUX Out: Enable / Disable per tick box

5.1.5. Waveform Generator Module SWM 828 5

The SWM 828 waveform generator module features two channels that can each generate a voltage profile consisting of a top hat (rectangular shape), sawtooth (triangular shape), or a sum of both components. The control elements defining the pulse shapes of the SWM 828 are shown in fig. 33. Both channels of a module can be configured independently from each other.

The final waveform generated at the physical output port of the SWM 828 module corresponds to the sum of the voltage profile components of both channels. It is possible to configure a channel to not output a waveform by setting both its pulse amplitude and ramp slew rate to zero.

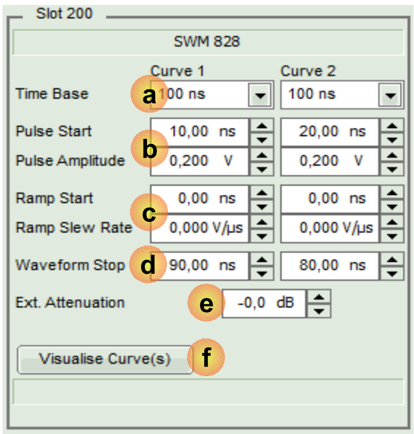

Fig. 33: Control elements for the SWM 400

a **Time Base:**

This setting defines the time base (or time window) in which the waveform will be generated. The time base can be set individually for both channels and selected from the drop down box. Three time base lengths are available: 33, 100, or 330 ns. The time values of the *Pulse Start*, *Ramp Start*, and *Waveform Stop* settings must lie within the selected *Time Base*.

b Pulse Start and Pulse Amplitude:

The characteristics of the top hat waveform component are defined by these two settings. The *Pulse Start* setting regulates the time delay between the start of the time base and the onset of the rectangular top hat component. This value (in ns) should not lie outside of the defined time base or after the *Waveform Stop* (d) time.

The amplitude (height) in V of the top hat component can be set through the *Pulse Amplitude* spin edit box. The maximum value for the pulse amplitude is 1 V.

The rectangular top hat pulse will thus start at the time point corresponding to the *Pulse Start* value, rise to a voltage value equal to the *Pulse Amplitude* setting, and run until the *Waveform Stop* time is reached.

c Ramp Start and Ramp Slew Rate:

These two settings are used to define the characteristics of the sawtooth component. The *Ramp Start* value is used to define the starting time point for the signal component. Again, this value (in ns) should not lie outside of the selected time base or after the *Waveform Stop* (d) time. As with the top hat component, the sawtooth ramp will run unit the *Waveform Stop* time has been reached.

The generated voltage ramp is linear with a slope defined by the *Ramp Slew Rate* (in V / µs). The highest value available for the *Ramp Slew Rate* is 20V / µs. The final amplitude of the sawtooth component will be the product of the *Ramp Slew Rate* and the ramp duration (which is equal to *Waveform Stop* minus *Ramp Start* time).

Please note that if the ramp start is set earlier than the top hat pulse start time, the ramp voltage profile during that time interval will not be present in the output signal. In this case, the amplitude of the sawtooth component is added to the top hat pulse at its onset. The value to be added will, however, correspond to the actual amplitude of the sawtooth component at this point of time (i.e. equal to the product of the *Ramp Slew Rate* and the time difference between the pulse and ramp start).

For example, if the *Ramp Start* time is set to 10 ns and the *Pulse Start* is set to 20 ns, the time difference would be 10 ns. During these 10 ns, the ramp voltage profile will not be added to the total output signal. Once the 20 ns mark is reached, the top hat pulse starts and the actual amplitude value of the ramp is added to it. If we assume a *Pulse Amplitude* setting of 0.2 V and a *Ramp Slew Rate* of 0.2 V / µs, the total amplitude at the time point t = 20 ns will be:

$$0.2\ \text{V} + (0.2\ \text{V} / 10^3\ \text{ns} * 10\ \text{ns}) = 0.202\ \text{V}$$

However, if, in the same case, the Ramp Start time had been set coincident with the top hat pulse onset at 20 ns, the total amplitude would have been 0.2 V. Since the ramp starts with the top hat pulse, it has not yet generated an amplitude that could be added.

d Waveform Stop:

The *Waveform Stop* settings indicates at which point in the *Time Basis* the two curve components will stop. This value should lie within the selected Time Basis and at a later time point than *Ramp Start* and *Pulse Start* settings.

e Ext. Attenuation:

The signal attenuation value that can be set here is only used for the curve visualization, i.e. the voltage signal intensity of the calculated curves is reduced. This value has no effect on the voltage of the signal generated at the output of the SWM 828 module. A physical attenuator has to be inserted between the SWM 828 output port and the VCL 828 input in order to affect the intensity of the voltage signal.

Please note that the maximal voltage allowed per SWM 828 channel is 1 V. As the curves from both channels are simply added, the maximum allowed voltage per VCL 828 input port is 2 V. Make sure that you insert appropriate attenuators between the output and input ports, so that these limits are not exceeded.

f Visualise Curve(s):

Clicking on this button opens a new window showing a visualization of the output signal and each single component. The Visualise Curve(s) window layout is shown in fig. 34. The window comes with several control elements allowing to select which curves or sum of curves are displayed as well as many options for customizing their looks.

Please note that the displayed curves will be automatically updated after a value in any spin edit box has been changed (once that field loses focus).

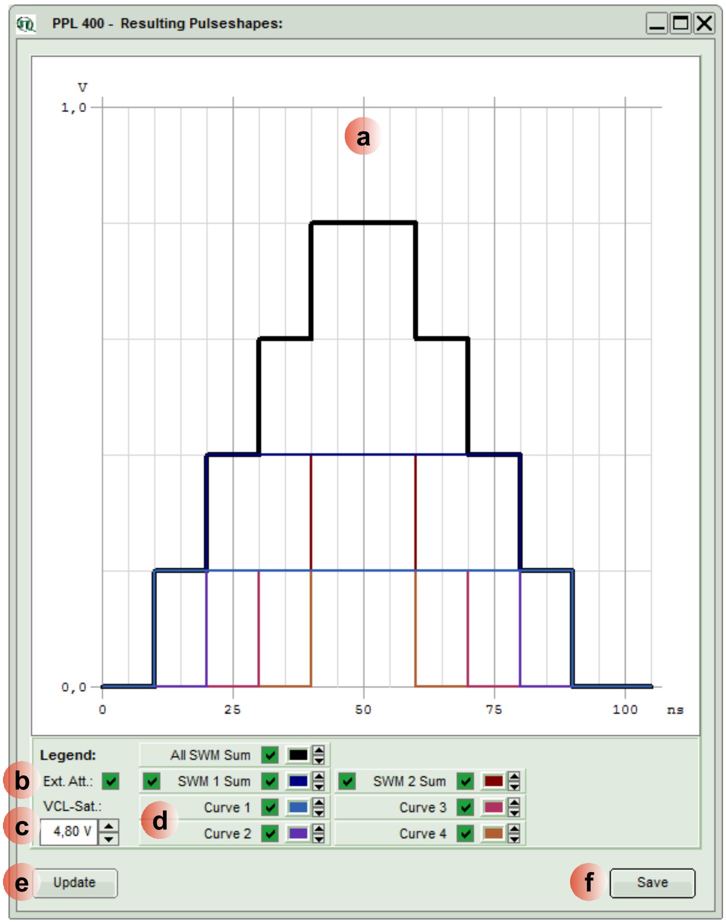

Fig. 34: Visualise Curve(s) window

a Main display window

The main display window contains a graphical representation of curves for each channel as well as the sums for each module and the total sum for both modules. Each of these elements can be individually displayed or hidden. Furthermore, the appearance (line width and color) of each element can be customized.

Ext. Att.

The *Ext. Att.* check-box allows to either apply or remove the external attenuation (per module) to the graphs shown in the main display window. If the check-box is ticked, the attenuation values defined in the SWM 828 control panel are applied to the calculated curves. By unchecking this box, the non-attenuated amplitude values will be displayed. Enabling the *Ext. Att.* function is very useful to determine which attenuators have to be inserted bewteen the SWM 828 output and the VCL 828 input ports (i.e. staying below the VCL 828 saturation voltage).

Please note that the attenuation values set in the SWM 828 control panel are only affecting the calculated curves in the visualization window and have no effect on the physical signal generated at the output port.

c VCL-Sat.

This spin edit box allows setting a voltage saturation value for the laser diode. The value is used to draw a horizontal dotted line in the main display window, making it possible to quickly check if the overall signal amplitude is lower than the VCL 828 saturation voltage.

Note that this value is only used for display purposes and has no bearing on the real saturation voltage of the real diode in the VCL 828 module. The latter is a fixed value and depends on the electronics of your VCL 828 module (see Laser Delivery Report in the Appendix).

d Display Options for Curves and Sum of Curves

The check-boxes and spin edit fields provided in this area of the “Visualise Curve(s)” window allow to fine tune the appearance as well as easily display or hide each curve or sum of curves. If a check-box is ticked, the corresponding element will be displayed, while un-checking it will hide it. The check-boxes to the left of the “*SWM 1 sum*” and “*SWM 2 sum*” will show or hide all components related to the respective SWM 828 module.

Clicking on the colored field of the spin edit box brings up a color picker, allowing to change the color of the corresponding line. The arrow up and down icons to the right of the color field control the line width. Clicking the up arrow will increase the line width, while the down arrow will decrease it.

e “Update” Button

This button can be used to refresh the contents of the main display window. Note that the main display does also automatically update once a spin edit field has been modified and lost it focus. Thus it is not mandatory to press the “Update” button to apply the changes.

f “Save” Button

By pressing this button, the contents of the main display window can be exported as a picture in GIF, JPEG, PNG or BMP format.

5.1.6. Voltage Controlled Laser Module VCL 828 6

The voltage controlled laser module VCL 828 has a thermoelectric cooling element in order to thermally stabilize the laser diode. The set-point temperature can adjusted in in the VCL 828 control panel (see fig. 35). The temperature setting range is from 15 to 55 °C. The current state of the thermal stabilization system is indicated by the status LED on the VCL 828 front panel (see fig. 18). Operating the laser diode at higher temperatures can lead to a shift in its central emission wavelength.

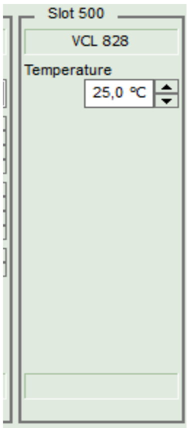

Fig. 35: Control element for the VCL 828

5.1.7. Presets 7

Two working configurations can be saved and recalled under in the frame labeled *Presets*. Each preset stores all working parameters of the device.

The currently applied configuration can be saved by clicking on the *Store Preset 1* or *Store Preset 2* button (see fig. 36). A pop up window gives the possibility to include a short comment with a maximal length of 64 characters for each stored configuration (see fig. 37). A stored configuration can simply be recalled by clicking on the button labeled *Recall Preset 1* or *Recall Preset 2*.

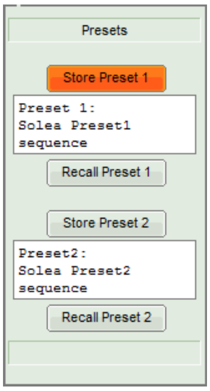

Fig. 36: Save a configuration

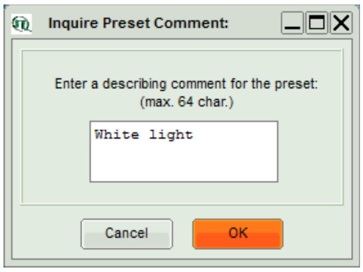

Fig. 37: Edit comment for a preset

Note: The presets are stored in the internal memory of the device and not on the host computer. They can therefore also be recalled if the device is connected to a different host computer.

CAUTION: Clicking on a *Recall Preset* leads to an immediate configuration change without the need to manually apply the changes! The process itself can, however, take some time depending on the difference between current and recalled settings!

5.1.8. “About...” button 8

Extended information about the device, including hardware version, serial number, operating hours, software and firmware version etc. can be brought up by clicking on the button labeled *About...*

For every support request its is recommend to save the entire information by clicking on the button labeled *Copy Support Infos* (see fig. 38), save the information as a plain text file, and send it per mail to info@picoquant.com.

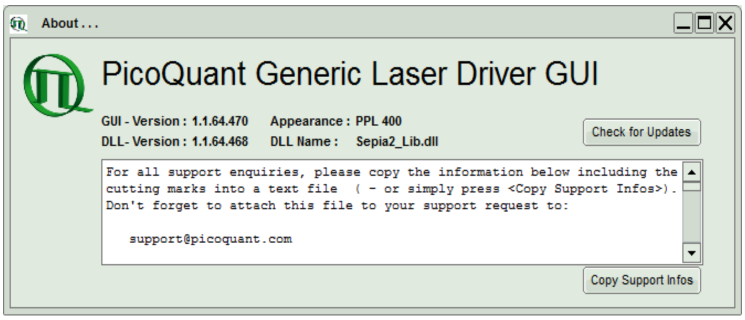

Fig. 38: The “About” window includes extended information about the status of the device

It is also possible to search for possible software updates by clicking on the button labeled *Check for Updates* (Fig. 38). If an update is available, a download link to the latest version will be provided.

6. Examples / Modes of Operation

In this chapter, four practical examples for generating different pulse forms and sequences with the PPL 400 laser driver. After starting up the laser driver software, the main GUI window containing control panels for all detected modules appears (see fig. 20).

The main GUI window will display either one or two SWM 828 control panels, depending on the number of physical modules present in the PPL 400 mainframe. Each control panel features a set of pulse parameters for each of the two waveform generator channels (curves) present in the module.

Each parameter set includes settings for defining the pulse shape, consisting of the time base, top hat pulse amplitude and start, ramp start and slew rate, as well as wave stop time. These parameters allow to generate in each channel a pulse shape built up from a linear combination of a top hat and / or sawtooth profile element. Note that all parameters for a single channel can be set independently from the others channels.

To summarize: the pulse shape of a curve is obtained by the linear addition of its top hat and sawtooth profile elements (if present). The total pulse profile generated by a single SWM 828 module consists in the linear sum of the pulse shapes defined by its two channels. Up to two SWM 828 modules can each provide a pulse shape to the VCL 828 laser module. Thus the final pulse profile can be defined by a combination of up to 4 top hat and / or sawtooth profile elements (1 of each type per curve, 2 curves per module, up to 2 modules per PPL 400).

6.1. Defining a Pulse Shape

In this example, a pulse shape with two distinct peaks is constructed within the longest time base, corresponding to a 330 ns window for each curve. All curves are using the same time base in these examples for the sake of simplicity. However, this is not mandatory as the time base can be set independently for each of them. Please note that the “double peak” pulse shape defined here will be used for the remaining examples in this chapter.

The visualization of the desired pulse shape and settings for the two SWM 828 modules is shown in fig. 39 and 40. The first pulse shape consists of a flat top + sawtooth structure (A), which is generated from the combination of curves 1 and 2.

In this case, curve 1 consists only of a top hat element with a pulse amplitude of 0.5 V and start time of 50 ns. The sawtooth element is not active since both its ramp slew rate and start time are set to zero. Curve 2 is configured to contain both a top hat and a sawtooth profile element. The start time of the top hat pulse occurs at 50 ns with an amplitude of 0.6 V. The sawtooth ramp starts at 100 ns and is set to have a slew rate of 8 V/µs. The wave stop time for both channels is set to 150 ns.

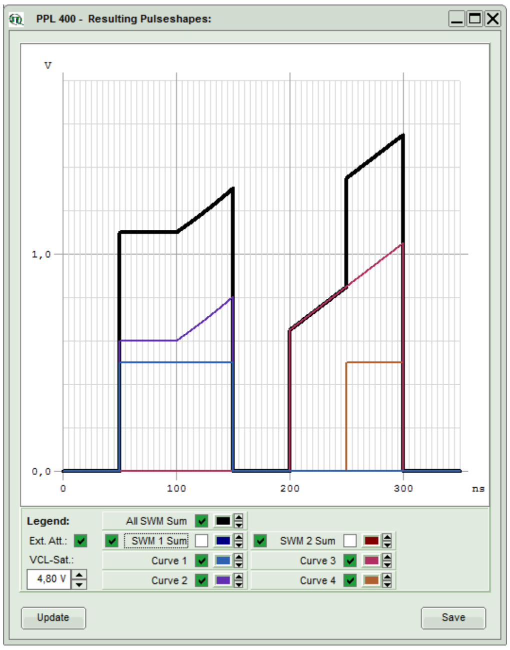

Fig. 39: Pulse shape to be used in the examples.

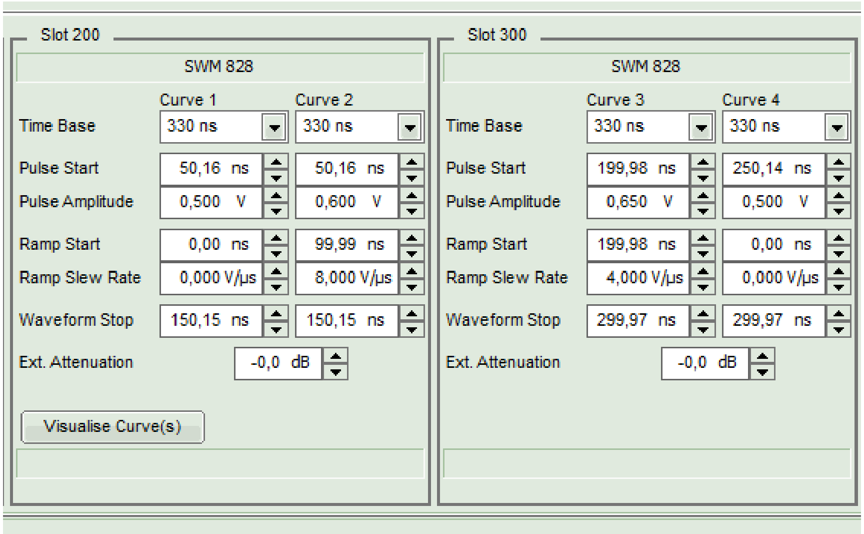

Fig. 40: Settings of the SWM 828 modules for the described pulse shape.

The pulse shape generated by the first SWM 828 module is obtained by adding the pulse elements from curves 1 and 2 (displayed as a thick black line in fig. 39). Since the top hat pulse elements of both curves start at 50 ns, the overall amplitude will be 0.5 V + 0.6 V = 1.1 V. The sawtooth element starts at 100 ns and ramps the amplitude from 1.1 v to 1.5 V over a time period of 50 ns.

Note that this pulse shape could have also been realized by using only one curve. In this case, the settings would include a top hat pulse element starting at 50 ns with an amplitude of 1.1 V and a sawtooth ramp staring at 100 ns with a slew rate of 8 V/µs.

The second part of the pulse structure (B) is constructed by combining curves 3 and 4. The pulse shape of curve 3 consists of both a top hat and sawtooth element. The top hat pulse and sawtooth ramp start times are both set to 200 ns, with an amplitude of 0.65 V and a ramp slew rate of 4 V/µs. Curve 4 consists only of a top hat pulse element with a start time of 250 ns and an amplitude of 0.5 V. Both curves have their wave stop time set to 300 ns.

The pulse shape generated by the second SWM 828 module is obtained in a similar way by adding the elements of curves 3 and 4 (shown as thick black line in fig. 40). Since the top hat and sawtooth elements in curve 3 have the same start time, the pulse appears at 200 ns with an amplitude of 0.65 V and the linear ramp begins also at that time. Adding the top hat element from curve 4 results in an amplitude jump at 250 ns from 0.85 V to 1.35 V. The ramping up of the voltage then continues with the same ramp slew rate.

Note that in this case, the pulse shape cannot be realized with using only one curve, as two top hat pulse elements are required. Also, setting the ramp start time before that of the top hat pulse will lead to a different behavior. The voltage will ramp up during this time difference, but will not be included in the output profile. The pulse profile will only start with the onset of the top hat element and the current amplitude value of the sawtooth element will be added to it (i.e. ramp slew rate multiplied by the time difference).

6.2. Shaped Pulses at Defined Repetition Rates

A detailed description on how to generate complex pulse patterns with the SOM 828-D along with step-by-step examples can be found in the PDL 828 “Sepia II” manual, chapters 5 and 6. This manual is automatically installed along with the laser driver software package.

The SOM 828-D control panel in the main GUI window can be used to output the desired pulse shape from the VCL 828 laser module at a defined repetition rate. In this example, we wish to generate the shaped pulses at a repetition rate of 1 MHz. The settings required to do so are summarized in fig. 41.

The main clock rate of 1 MHz can be realized by selecting the internal oscillator running at 64 MHz and choosing a divider value of 64. Since the desired pulse shape requires two independent SWM 828 modules to generate it, each of these has to be connected to a separate NIM output channel of the SOM 828-D oscillator module. In the present example, the first SWM 828 module (curves 1 and 2) is connected to the NIM output channel 1 while the second waveform generator module (curves 3 and 4) is attached to output channel 2.

In order to realize the pulse pattern at the desired repetition rate, the following settings need to be made in the SOM 828-D control panel (see also fig. 41). We need one pulse from both SWM 828 module at the same time to from the complete “double peak” pulse shape defined in the previous section. Thus, the “*OutEna*” check-boxes in the SOM 828-D control panel for the output channels 1 and 2 need to be ticked, while channels 3 to 8 have to be deselected. This way, the sequencer will only trigger pulses for the first two channels.

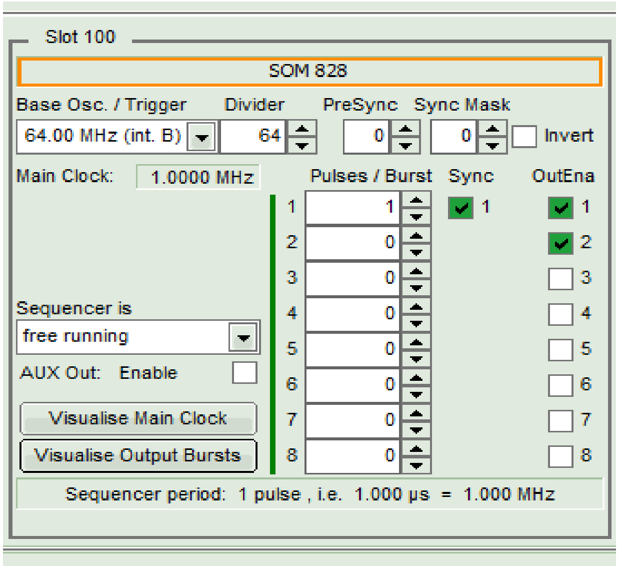

Fig. 41: SOM 828-D control panel set for a pulse form composed four channels from 2 SWM 828 modules that are delivered from the laser diode at an effective repetition rate of 100 kHz.

A value of 1 has to be set in the “*Pulses / Burst*” field for output channel 1, meaning that exactly one trigger pulse will be generated at this output channel per sequencer period. The “*Pulses / Burst*” value for channel two was set to 0, allowing this channel to copy the burst pattern of the first one and send the copied trigger signal simultaneously to the second SWM 828 module.

Finally, the “Sync” check-box for output channel 1 should be ticked, so that a synchronization trigger signal is generated at the SYNC OUT port of the SOM 828-D every time when the two SWM 828 modules are triggered. The signal from this port can be used to synchronize other components such as counting or detection electronics with the laser pulses.

Fig. 42 shows both the detected individual laser pulse shape from the VCL 828 module (left panel) as well as pulses delivered at a constant repetition rate of 1 MHz.

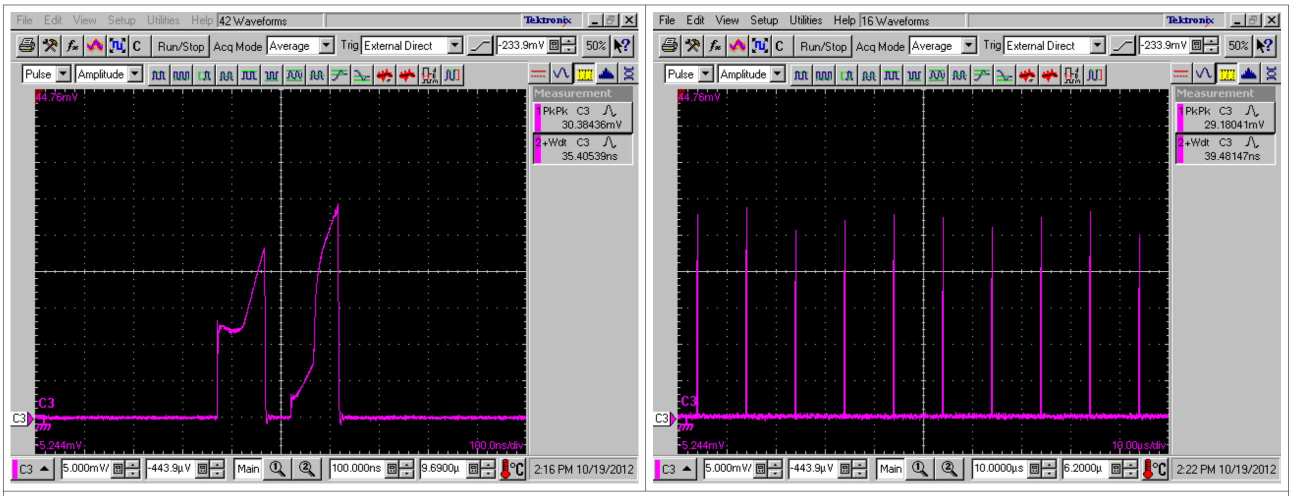

Fig. 42: Laser emission from the VCL 828 module resulting from the SOM settings in Fig.41 monitored via a fast photodiode and oscilloscope showing an individual pulse shape at 500 ps/div (left) delivered at a constant repetition rate displayed at 5 ms/div (right)

6.3. Shaped Pulses in Defined Bursts and Burst Rates

In this example, a burst consisting of three pulses from the first SWM 828 module only with a main clock rate of 1 MHz and a burst rate of 100 kHz is generated. The corresponding settings are summarized in fig. 43.

The base clock rate remains unchanged (internal oscillator at 64 MHz with a divider of 64). The “Pulses / Burst” value for output channel 1 is set to 3 and its “*OutEna*” and “Sync” check-boxes are ticked. The “Out-Ena” check-box for channel 2 is deselected. Thus only output channel 1 will generate trigger signals for the SWM 828 module and the corresponding SYNC OUT signal.

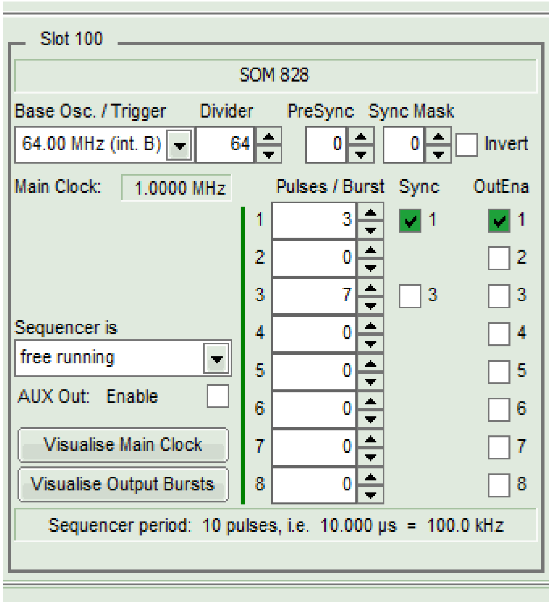

Fig. 43: SOM 828-D control panel set for a pulse form composed two channels in one SWM 828 modules in bursts of 1x3 pulses at a pulse rate of 1 MHz and a burst rate of 100 kHz.

Note that the “Pulse / Burst” value for output channel 3 has been set to 7. This has been done in order to have 10 pulses per sequencer period, leading to sequencer period length of 10 µs (1 / 10^6 MHz = 10^{-6} s = 1 µs per pulse; 10 pulses = 10 µs). This, in turn, means that the sequencer will run at a repetition rate of 100 kHz. Note that since output channel 3 is not active, there will be no electrical pulses generated at the corresponding port, but the pulses will still be counted by the sequencer.

The measured laser intensity profile from VCL 828 module and the pulse burst sequence obtained by using the settings described above are shown in fig. 44.

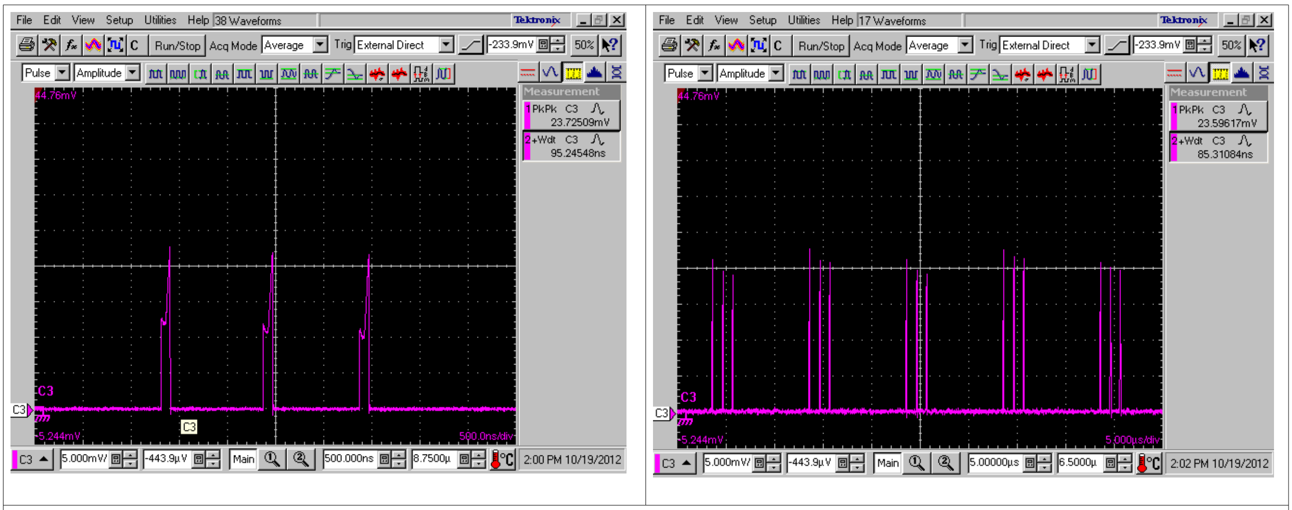

Fig. 44: Laser emission from the VCL 828 module resulting from the SOM 828-D settings in Fig. 43 monitored via a fast photodiode and oscilloscope showing the pulse sequence in a single burst at 500 ps/div (left) and the burst rate at 5 ms/div (right)

6.4. Alternating Pulse Shapes at Defined Burst Rates

The sequence described in this example consists of two shaped pulses from the first SWM 828 module followed by two from the second one. The main clock rate is kept at 1 MHz with a burst rate (sequencer repetition rate) of 100 kHz. The settings needed for this pulse pattern is shown in fig 45, while fig. 46 contains the measured laser intensity profile and pulse sequence.

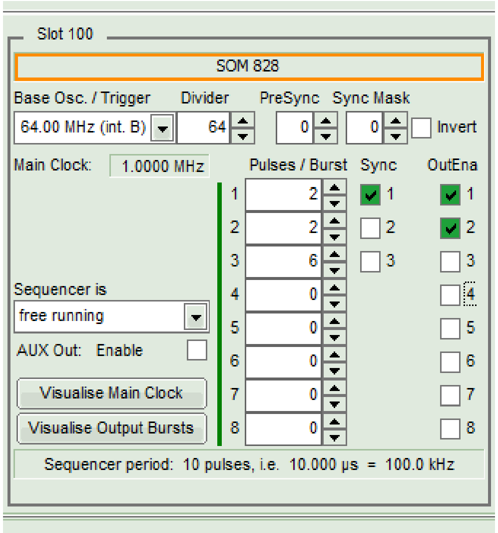

Fig. 45: SOM 828-D control panel set for alternating pulse shapes each composed of two channels from one of the two SWM 828 modules in bursts of 2x2 pulses.

In order to obtain the desired burst rate of 100 kHz with a main clock rate of 1 MHz, we need to have a sequencer period with a length of 10 pulses (see the previous example for calculation details). As the two shaped pulses from each SWM 828 module are to appear one after the other, the "*Pulses / Burst*" setting for output channel 1 and 2 are both set to 2. Inserting a value of 0 for the "*Pulses / Burst*" value in output channel 2 would lead to the four pulses being generated simultaneously.

To reach the required 10 pulses per sequencer period, we need to insert a value of 6 in the "*Pulses / Burst*" field for another channel. In this case output channel 3. The "*OutEna*" check-boxes for output channels 1 and 2 need to be ticked, so that the corresponding electrical pulses are generated. Since the check-box for output channel 3 is deselected, that channel will not generate such signals, but the number pulses will still be counted by the sequencer. Note that the "Sync" check-box is only active for output channel 1.

This set-up produces the desired pulse pattern (two shaped pulses from the first module followed by two from the second one) with the proper burst rate of 100 kHz.

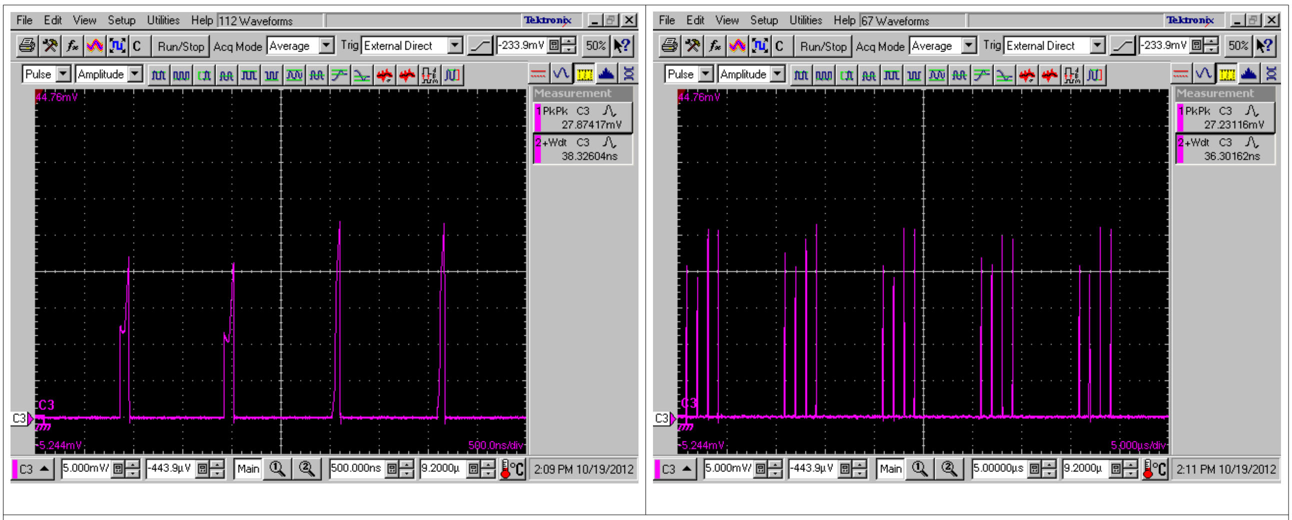

Fig. 46: Laser emission from the VCL 828 module resulting from the SOM 828-D settings in fig. 45 monitored via a fast photodiode and oscilloscope showing the pulse sequence in a single burst at 500 ps/div (left) and the burst rate at 5 ms/div (right).

6.5. Alternating Bursts of Pulse Shapes at Defined Burst Rates

The burst pattern described in this example is very similar to the previous one: it consists of two shaped pulses for the first SWM 828 module, followed two from the second one. The difference here being that a pause of 1 µs is inserted between the two pulse packets. The settings to be made in the SOM 828-D control panel are summarized in fig. 47.

This is done by first changing the connection of the second waveform generator module from output channel 2 to 3. The main clock setting is kept at 1 MHz as in the previous example and the sequencer period should still have a length of 10 µs (corresponding to 10 pulses).

The "*Pulses / Burst*" value for output channels 1 and 3 have been set to 2 and their "*OutEna*" check-boxes ticked in order to generate the respective packets of two pulses at the output ports of the SOM 828-D module. Output channels 2 and 4 had their "*Pulses / Burst*" values set to 1 and 5, respectively. Since these two channels should not generate an electrical signal, the respective "*OutEna*" check-boxes have been disabled.

The total number of pulses is again 10 (2+1+2+5), thus the sequencer period is equal to 10 µs and the burst rate 100 kHz. Note that only output channel 1 has been selected to generate the synchronization pulses ("Sync" check-box enabled).

The resulting, measured pulse and burst patterns are shown in fig. 48. One can clearly see the single pulse pause between the two groups of shaped pulses from the two SWM 828 modules.

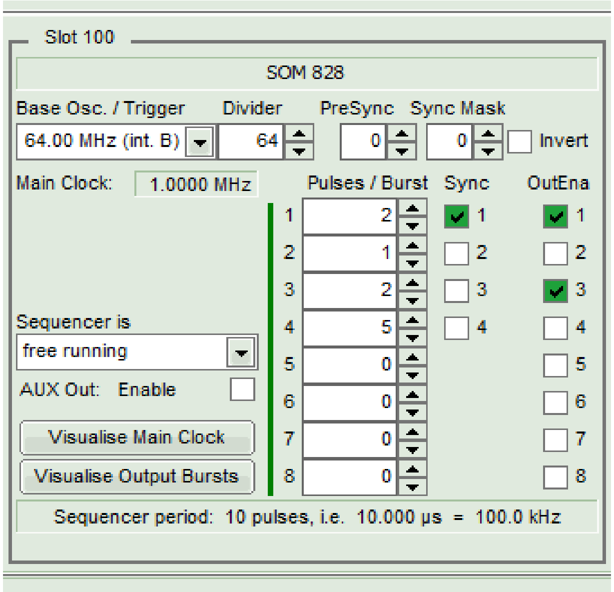

Fig. 47 SOM 828-D control panel set for alternating pulse shapes each composed of two channels from one of the two SWM 828 modules in bursts of 2x2 pulses at a pulse rate of 1 MHz separated by a pause pulse and a total burst rate of 100 kHz.

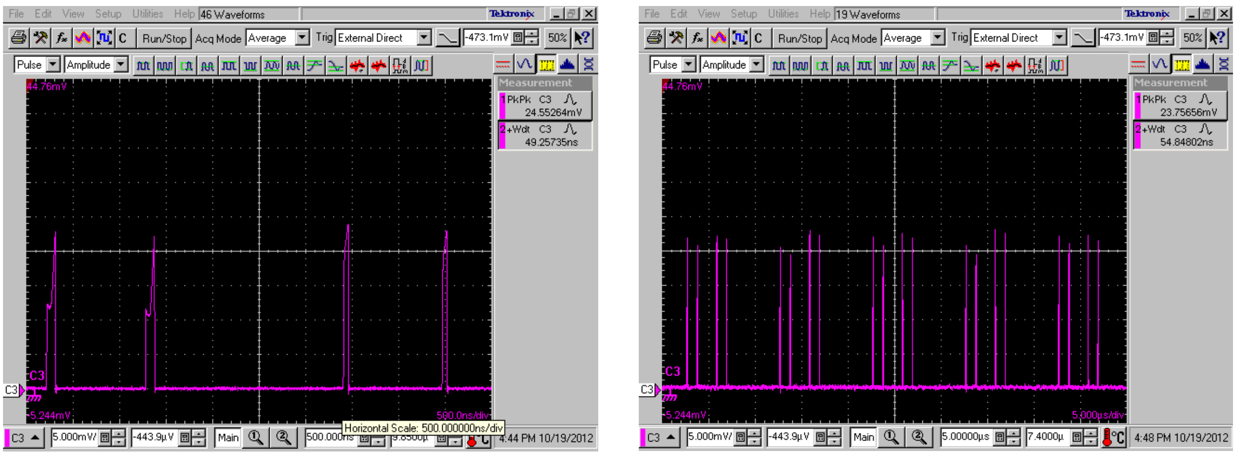

Fig. 48: Laser emission from the VCL 400 module resulting from the SOM settings in fig. 47 monitored via a fast photodiode and oscilloscope showing the pulse sequence in a single burst at 500 ps/div (left) and the burst rate at 5 ms/div (right).

7. Technical Data / Specifications

Voltage controlled laser module (VCL 828)

Inputs.. two analog inputs for output from max. two SWM 400 modules
.... max. superimposed analog voltage: 1 V for full optical output power

Optical Output
Central wavelength.............................. 1030, 1062, 1950 nm; others on request
Spectral width..................................... < 1 nm
Output Power...................................... 50 mW after single mode fiber
Output connector................................ FC/APC
Output stability.................................... 3% rms

Waveform generation module (SWM 828)

Input... 1 external trigger (NIM) for output from SOM 828-D module
Outputs.. analog voltage 0 to 1 V (waveform defined by software settings)
.... status control; synchronization output
Number of waveform generators .... 2 per module; up to 4 per PPL 400 mainframe

Waveform parameters
Time base length................................. 33, 100, or 330 ns
Square pulse amplitude........................ freely selectable from 0 to 1 V
Square pulse start and stop time.......... freely definable within chosen time base
Sawtooth (ramp) slew rate.................... freely selectable from 0 to 20 V/µs
Sawtooth (ramp) start / stop time.......... freely definable within chosen time base

Operation modes
Continuous pulse mode....................... pulse repetition rate from 196 kHz to 1 MHz and single pulse
Burst pulse mode................................ up to 16.7 million pulses per burst; pulse repetition rate from 196 kHz
.... to 1 MHz; burst repetition rate from 196 kHZ to 500 kHz

Oscillator module (SOM 828-D)

Input.. 1 external trigger (BNC)
Outputs.. 8 trigger (NIM), 1 synchronization (NIM)
Oscillator type..................................... crystal locked
Base frequencies................................. 50, 64, or 80 MHz (selectable)
Repetition frequency........................... user selectable, derived from selected base frequency or external
.... trigger source by division through any integer factor from 1 to 65536

Synchronization output
Timing.. synchronous to repetition frequency, timing position stepwise
.... adjustable within the limits of the repetition frequency, step size
.... equals base oscillator period
Amplitude.. < -800 mV into 50 Ω (NIM)

External trigger input
Amplitude.. -5 to +5 V (maximum limits)
Trigger level.. -1 to +1 V

Frequency range................................. up to 40 MHz

Burst
Burst length... up to 16.7 million pulses

Mainframe

Power supply....................................... 100 to 250 VAC, 50/60 Hz, max. 250 Watt
Dimensions... 464 x 310 x 140 mm (w x d x h)

Computer

Operating System................................ Windows™ 7 / 8 or 8.1 / 10
PC Interface.. USB 2.0

Retraction of Old Devices

Waste electrical products must not be disposed of with household waste. This equipment should be taken to your local recycling center for safe treatment.
WEEE–Reg.–No. DE 96457402

8. Support

8.1. Returning Products for Repair

If you have serious problems that require the device to be sent in for inspection / repair, please contact us at: support@picoquant.com and send us the output of the “About..” window (see chapter 5.1.8). In case the device needs to be send to PicoQuant for repair, please request a RMA number before shipping the device. Observe precautions against static discharge under all circumstances in handling, packaging and shipping. Use original or equally protective packaging material. Inappropriate packaging voids any warranty.

8.2. PicoQuant Community Forum

This forum is intended as a platform for users of PicoQuant's systems, components and software packages. It is not strictly limited to software related questions. As PicoQuant products cover a wide range of applications from single molecule experiments to life sciences and material science, discussions of the scientific background are of course welcome. The forum can be found at http://forum.picoquant.com

9. Legal Terms

9.1. Copyright

9.2. Trademarks

10. Further Reading

10.1. PicoQuant Bibliography

PicoQuant maintains a database of publications mentioning PicoQuant devices. It can be found at our website http://www.picoquant.com/biblio.php. It is a valuable source if you would like to know which laboratories are using PicoQuant products or how broad the field of various applications is. Of course you are invited to sent us copies of your papers or links to the publications to be included in this database.

10.2. Download of Technical Notes / Application Notes

PicoQuant, along with our customers, continuously writes and publishes short documents about techniques, methods, and applications that can be implemented with our hardware or software. The download section can be found at http://www.picoquant.com/appnotes.htm

If you want to contribute to this section, you are also very welcome to contact us with your ideas.

11. Appendix

This section contains the description of the firmware start-up diagnostic procedure, the list of abbreviations and a table of the figures encountered in this user manual.

11.1. Firmware Start-Up Diagnosis

After power up, several phases during the self test sequence can be distinguished:
Self Test Procedure

Phase id.	Start up phase	Duration	Status light(s)
	booting the controller	approx. 5.0 sec	off
00	checking controller hardware	approx. 0.5 sec	continuously red
10	initialize device mapping	min. 4.0 sec	blinking yellow (or red *and* green)
20	device mapping		
30	checking frame	depends on configuration of the PPL 400	blinking green
40	checking modules		
50	checking configuration		
60	modules' calibration		
70	modules' initialization		
80	successfully up and free running, ready to release laser soft lock	until error detection or power down	continuously green
??	on error	repeating sequence …. until power down	long red interval, pause, yellow blink code…, pause, long red interval, pause, …

If a rack remains blocked by a failure, the error may be further diagnosed by software. Start e. g., "ReadAll-DataByDelphi.exe" from the demo section of the programming library. This program will help to identify the reasons. Please refer to separate manual for the API for details. If there is no USB host computer available that could run software tools, you may tell from observing the SCM828 "STATUS" indicator in which slot the error was detected. Counting the yellow flashes between the long red intervals gives the leading digit (i. e. the hundreds) of the slot number. If there is no yellow flash, an error was detected either in the back-plane of the frame or quite early before any module was individually activated.

Common reasons for a failure might be

- Failure of the power supply system
- Failure of the back-plane connecting the modules
- Failure of a module to identify or initialize properly

11.2. Abbreviations

BNC	British Naval Connector or Bayonet Nut Connector or Bayonet Neill Concelman
CAMAC	Corporations and Markets Advisory Committee
DLL	Dynamic Link Library
FC/APC	Ferrule Connector or Fiber Channel / Angled Physical Contact
FWHM	Full Width at Half Maximum
GUI	Graphic User Interface
IEC	International Electrotechnical Commission

BNC	British Naval Connector or Bayonet Nut Connector or Bayonet Neill Concelman
IRF	Instrument Response Function
LED	Light Emitting Diode
NIM	Nuclear Instrumentation Methods
NIR	Near infrared
OD	Optical Density
PM	Polarization Maintaining (fiber type)
RMA	Return Mechandise Authorization
SMA	Sub-Miniature version A (connector type)
TCSPC	Time-Correlated Single Photon Counting
TTL	Transistor-Transistor Logic
USB	Universal Serial Bus
WEEE	Waste Electrical and Electronic Equipment

11.3. Laser Delivery Report

The delivery report of your laser, including all final production test results for pulse shape, optical power, and line width is attached to this user manual. A PDF copy can be provided on request.

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