Solea Series

Supercontinuum Lasers:
Solea / Solea White
SoleaR / SoleaR White

PicoQuant

Externally triggerable,
wavelength tunable picosecond laser

User Manual

Document version 1.4.6

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1. Introduction

Please take the time to read this manual carefully before using the Solea laser. As the Solea laser is based on a class 4 laser source, chapter 2 Safety Related Instructions should be read with particular care.

The Solea devices are stand alone, computer controlled, supercontinuum white light laser sources with an unmatched flexibility in repetition rates. It is based on a unique combination of gain-switched, fiber-amplified laser diodes with exclusive, patented fiber pumping control[1] and well established, state-of-the-art photonic-crystal fiber for supercontinuum generation. The Solea is currently available in several versions: the Solea with a spectral range of 480 nm to 700 nm and the SoleaR with an extended spectral range (480 nm to 900 nm) and higher optical output power. Both devices are capable of emission wavelength selection as well as of supercontinuum output. The Solea White and SoleaR White devices have similar specifications but do not include an integrated emission wavelength selector.

A comparison of the spectral range, optical output power, and other features of the different members of the Solea supercontinuum laser family is given in Table 1 below.

Table 1. Feature overview of the Solea supercontinuum laser family.

Device Name	Wavelength Range	Output Power @ 40 MHz	Supercontinuum Emission	Wavelength Selection
Solea	525 – 700 nm (ECO mode) 480 – 700 nm (BOOST mode)	> 100 mW (ECO mode) > 250 mW (BOOST mode)	✓	✓
Solea White	525 – 700 nm (ECO mode) 480 – 700 nm (BOOST mode)	> 100 mW (ECO mode) > 250 mW (BOOST mode)	✓	
SoleaR	525 – 900 nm (ECO mode) 480 – 900 nm (BOOST mode)	> 250 mW (ECO mode) > 750 mW (BOOST mode)	✓	✓
Solea R White	525 – 900 nm (ECO mode) 480 – 900 nm (BOOST mode)	> 250 mW (ECO mode) > 750 mW (BOOST mode)	✓	

1.1. Variable Repetition Rates up to 40 MHz

A special feature of the Solea is its capability to be operated at various, freely adjustable repetition rates between 1 MHz and 40 MHz. The repetition rates can be either selected using an internal oscillator, providing six fixed, user-selectable repetition rates between 1.25 MHz and 40 MHz. Alternatively, the Solea can be triggered externally at any repetition rate between 1 MHz and 40 MHz. This unique feature permits synchronizing the Solea with other lasers for multicolor excitation schemes. The extinction between each pulse is complete, and thus classical, contrast limited pulse pickers are not needed.

1.2. Integrated Emission Wavelength Selector

The Solea and SoleaR include an integrated emission wavelength selector based on a tunable bandpass filter. The filter features a high side mode suppression ratio greater than OD 5 (50 dB), which makes it even suitable for single molecule detection. The wavelength selector permits setting the central emission wavelength to any value in covered spectral range. The band width of the spectral emission at the selected wavelength can be set to any value between 3 nm and 15 nm. Furthermore, the wavelength selector can be bypassed in order to have access to the available supercontinuum spectrum.

Please note that the emission wavelength selector is not included in the “White” versions of the Solea and SoleaR. These two device versions only allow for supercontinuum output.

1 Patent: DE102009056092

1.3. Pump Diode Management – Modes of Operation

A special feature of all Solea devices is the capability to be operated in two modes: “ECO” or “BOOST”. The modes differ by the amount of power supplied to the fiber amplifiers, which has a direct effect on the optical power level, the spectral shape of the supercontinuum output, and the lifetime of the Photonic Cristal Fibre itself.

ECO mode is the mode of choice for standard operation yielding emission in the spectral range between 525 nm to 700 nm (Solea) or 525 nm to 900 nm (SoleaR).

BOOST mode can be occasionally used if more power or emission at wavelengths between 480 nm and 525 nm are needed. Use of the BOOST mode accelerates the degradation of the Photonic Crystal Fiber (PCF) hence reducing its lifetime.

1.4. Power Density and Pulse Width

The Solea emits from a polarization maintaining single mode fiber with a usable spectral range between 525 nm to 700 nm (ECO mode) or 480 nm to 700 nm (BOOST mode). The spectral emission range of the SoleaR is extended to 900 nm in both modes.

The total output power of the Solea, without tunable bandpass filter, amounts to 100 mW (ECO mode) or 250 mW (BOOST mode), while the SoleaR provides output power of 250 mW (ECO mode) or 750 mW (BOOST mode) under the same conditions. Average spectral densities of 0.4 mW/nm (ECO mode) or 1 mW/nm (BOOST mode) can be achieved at 40 MHz repetition rate with all device versions.

After passing the tunable bandpass filter, the typical pulse width of all device versions is about 150 ps (FWHM). Each pulse is accompanied by a corresponding timing optimized synchronization signal, which can be used to trigger other components such as TCSPC electronics.

2. Safety Related Instructions

2.1. General Safety Instructions

LASER Warning!

The Solea and SoleaR lasers emit visible and infrared light. Infrared light is in not visible for the eye!

The following Table 2 summarizes the laser class ratings for the family members of the Solea supercontinuum laser.

Table 2. Laser class rating for the different Solea supercontinuum lasers.

Solea Model	Laser class rating
Solea	Class 3B / IIIb
Solea White	Class 3B / IIIb
SoleaR	Class 4 / IV
SoleaR White	Class 4 / IV

The SoleaR and SoleaR White lasers can emit light of laser class 4 / IV.

When using lasers with class 3B / IIIb and 4 / IV it is required to wear special eye protection (laser safety goggles).

The room in which the Solea or SoleaR is installed must be labeled as laser area.

According to laser safety regulations, a laser safety officer has to be named for class 4 / IV lasers.

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 (VIS and UV systems) and laser class 4 / IV 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 Solea and SoleaR lasers. Observe all safety precautions relevant to Class 3B / IIIb and Class 4 / IV lasers.
- Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.
- The laser power levels accessible **if the unit is opened** can reach laser Class 4 / IV levels and cause instant blindness, skin burns, and fires. Class 3B / IIIb or 4 / IV lasers can present a major hazard through exposure to the direct (intra-beam) or reflected (specular or diffuse) laser beams when the laser is inadvertently “on” and there is a direct line-of-sight path to the laser beam or its reflection.
- Therefore **do not open the device** during operation under any circumstances!

2.2. Safety Label on the Laser Device

The safety labels are visible on the front and on the back side of all Solea devices.

On the front side of all Solea devices, the safety label is located on the right hand side of the laser output aperture (fiber coupler), as shown in Fig. 1.

Fig. 1: Laser aperture, laser warning, certification and laser classification label. Left: for class 4 / IV laser product (SoleaR and SoleaR White); Right: for class 3B / IIIB laser products (Solea and Solea White).

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, as shown in Fig. 2.

The warning and classification label is located to the left of the identification label, as show in Fig. 2.

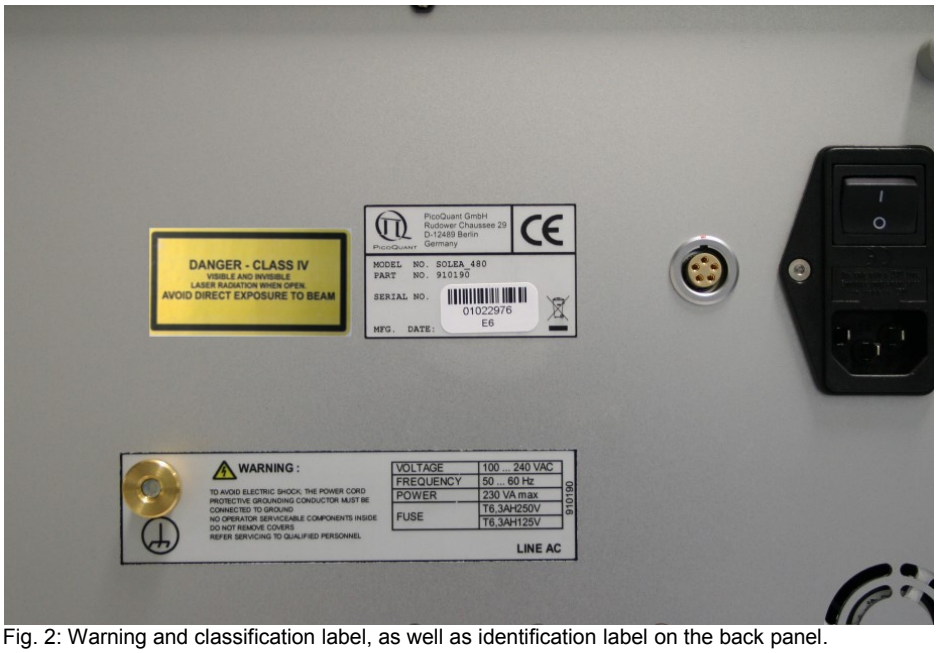

Fig. 2: Warning and classification label, as well as identification label on the back panel.

2.3. Remote Interlock Connectors and Manual Reset

In order to meet laser safety regulations for laser class 4 / IV devices, a hardware lock as well as a remote interlock connector are included in all Solea supercontinuum lasers. 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 plate of all Solea devices left of the key switch, as shown in Fig. 3.

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.

Your Solea device is delivered by default with an interlock bridge bypassing the connectors. Removing the bridge immediately deactivates the power to the laser.

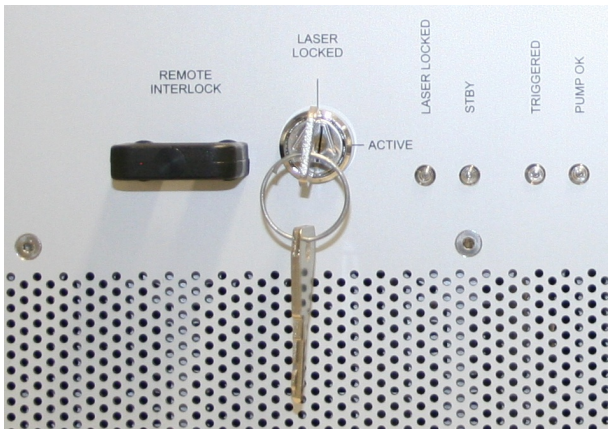

Fig. 3: Remote interlock connectors with interlock bridge

Important Note:

In order to comply with Laser Class 4 / IV regulations, laser output will be internally blocked if one of the following events occur:

- Power interruption during the operation of the Solea supercontinuum laser. Laser emission will **not** resume once power is restored.

- Interruption of the remote interlock circuit.
- Laser key switch is **not** in the *LASER LOCKED* position when the main power button is switched to the *ON* position (see chapter 4.1 Interface / Front Plane).
- Setting the laser soft-lock status in the GUI to *LOCKED*, i.e. laser emission will not be restored when switching the laser soft-lock back to the *UNLOCKED* state.
- Overheating of any internal laser diode due to too high external temperature is detected.

Once the hardware lock of the system has been triggered, the *LASER LOCKED* LED (see chapter 4.1 Interface / Front Plane) will permanently show red light, even when the laser key switch is in the *ACTIVE* position and the laser soft-lock in the GUI is in the *UNLOCKED* state (see chapter 5.1.3 Soft Locking and Unlocking of the Solea).

To unlock the system, a **manual reset** is needed. The **manual reset** is done by turning the laser key switch back into the *LASER LOCKED* position. Laser emission can then be reactivated by turning the laser key switch into the ACTIVE position and/or by deactivating the laser soft-lock in the GUI.

Please note that this safety feature is included in all Solea versions (even the ones specified as Laser Class 3b / IIIb products).

Make sure to follow all safety regulations.

Never try to remove the fiber from the fiber coupler of the Solea.

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

3. Installation and Quick Start

3.1. Unpacking the Solea

The Solea is delivered in a wooden crate and completely protected by four pieces of specially formed foam. Please note that the Solea weights approx. 32 kg. It is therefore advised not to unpack the laser alone.

To unpack the Solea, remove the upper lid of the wooden crate by lifting up the metal noses holding the lid in place with a flat head screwdriver, as shown in Fig. 47. Remove then the two upper foam pieces.

Carefully pull the Solea from the crate. The two bottom pieces of foam should stay in the crate.

It is recommended to put the two upper pieces of foam back into the wooden crate, close it and keep it in a storage room for any possible further shipping, e. g., returning the Solea back to PicoQuant for maintenance of the Photonic Crystal Fiber (PCF).

The Solea is delivered along with a power cord, a USB cable, a USB key including the standard control software, this user manual, and the laser delivery report. Please check that all these are included and, if in doubt, contact PicoQuant immediately.

3.2. Installing the Solea Software

Before installing and using the Solea, please make sure you have:

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

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

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

The Solea control software is supplied on a USB stick along with the laser. Installing the software is straightforward and performed through a step-by-step installation wizard. To install the software:

1. Insert the USB stick into the host computer.
2. Launch the program: *PQLaserDrv_Setup.exe*, which can be found in the USB root directory
3. Follow the on-screen instructions:

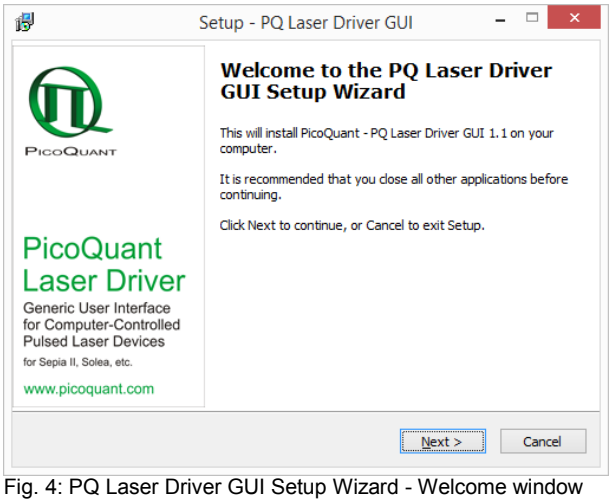

Fig. 4: PQ Laser Driver GUI Setup Wizard - Welcome window

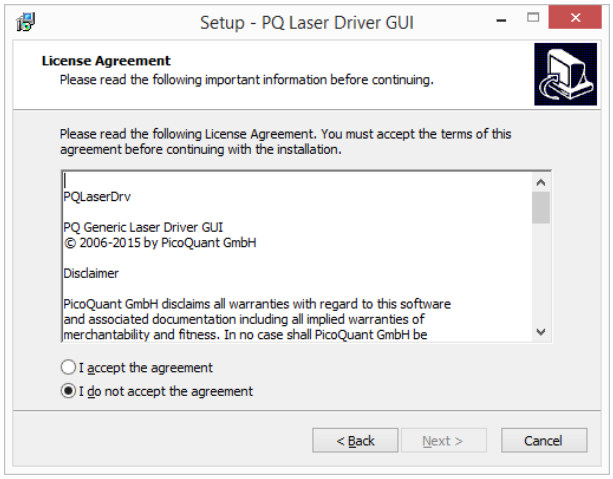

Fig. 5: PQ Laser Driver GUI Setup Wizard - Licence Agreement

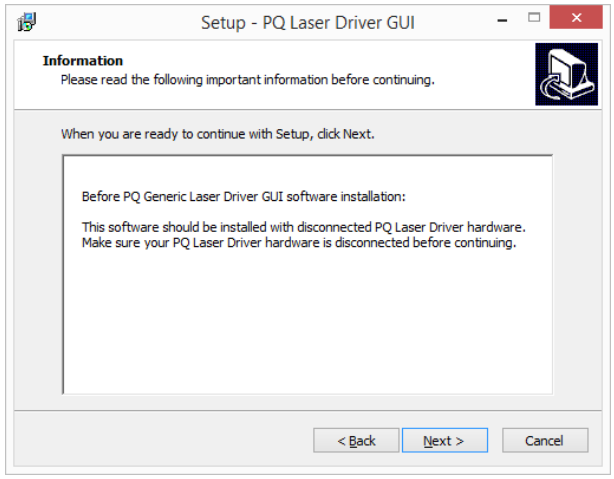

Fig. 6: PQ Laser Driver GUI Setup Wizard - Warning

Accept the License agreement and click *Next* when requested (See Fig. 4, Fig. 5, and Fig. 6).

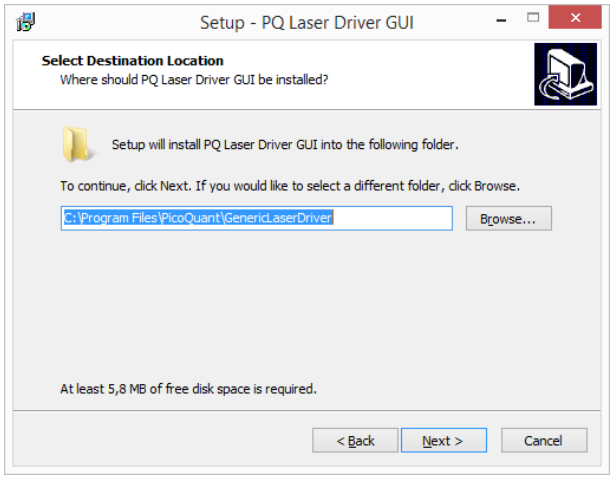

Fig. 7: PQ Laser Driver GUI Setup Wizard - Define target

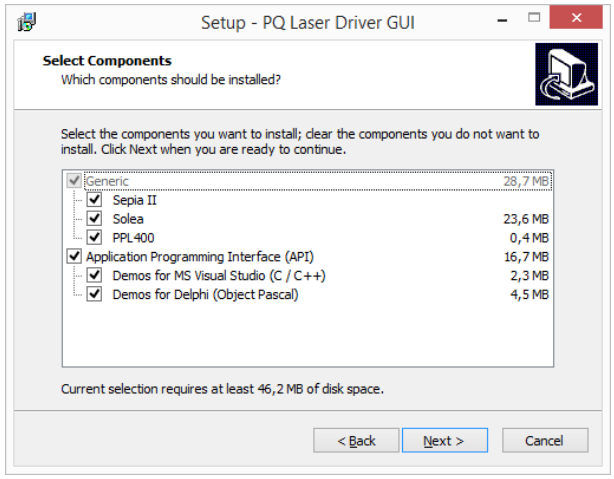

Fig. 8: PQ Laser Driver GUI Setup Wizard - Define devices

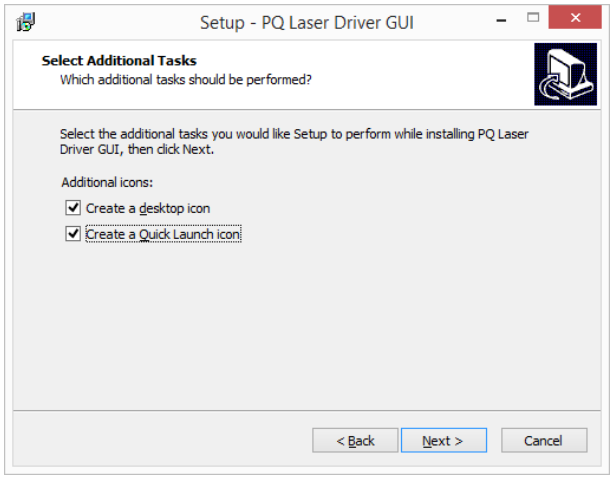

Fig. 9: PQ Laser Driver GUI Setup Wizard - Launch icons

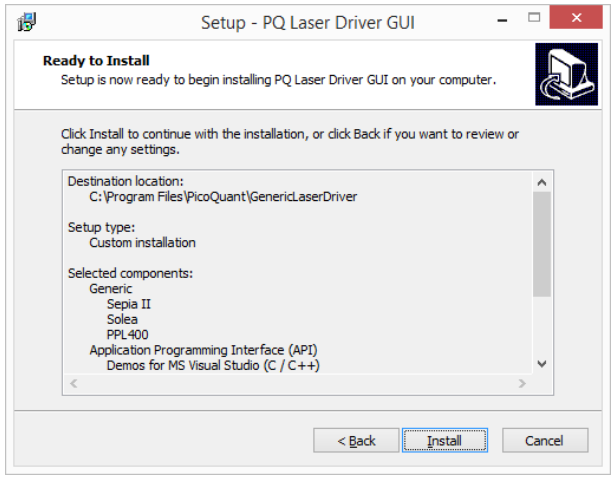

Fig. 10: PQ Laser Driver GUI Setup Wizard - Start installation

Define the target folder for the software installation (Fig. 7), the components to be installed (Sepia II, Solea and / or PPL 400, Fig. 8), and the launcher icon to be generated (Fig. 9). Click on *Next* to validate your choices and then *Install* to start the installation process, as shown in Fig. 10.

Important Remarks:

The PicoQuant Laser Driver Software can control not only the Solea laser but also the multichannel picosecond laser driver PDL 828 “Sepia II” or the PPL 400 from PicoQuant. In case you need to control a PDL 828 “Sepia II” along with the Solea, then it is necessary to install both components (see Fig. 8).

It is recommended to choose at least one of the suggested icon generation options (see Fig. 9). For each icon option chosen, the installer automatically creates two launcher shortcuts corresponding to the respective Bright and Dark PicoQuant color themes. For more detail about these software color themes please refer to paragraph 5.1 Solea – Graphical User Interface (GUI).

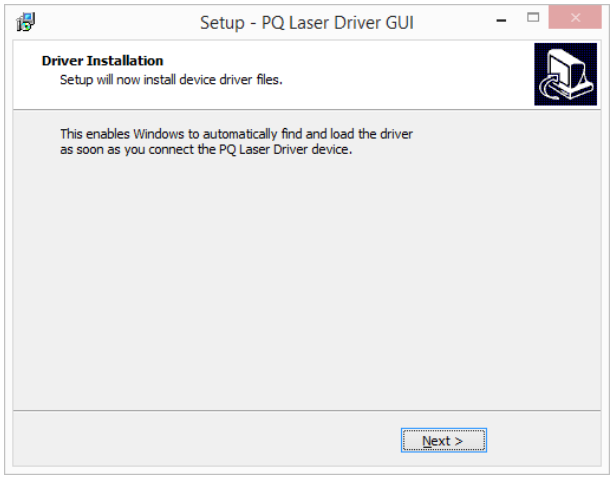

Fig. 11: PicoQuant Laser Driver GUI Setup Wizard - Driver installation

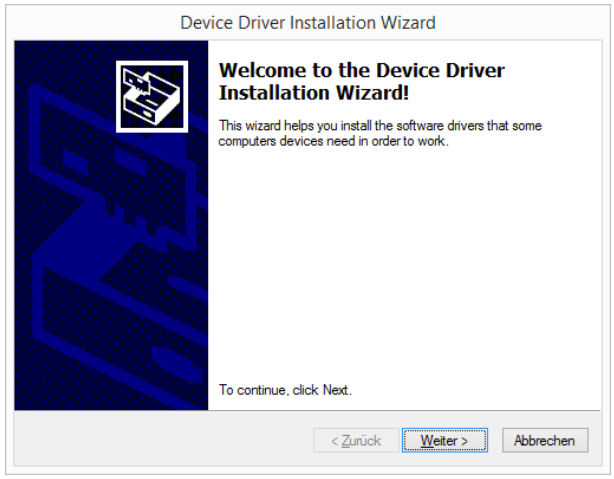

Fig. 12: PicoQuant Laser Driver GUI Setup Wizard - Driver installation

Click *Next* to continue with the installation of the drivers as shown in Fig. 11 and Fig. 12.

It is possible that a *Windows Safety Warning* window pops up. Should this happen confirm the installation when requested in order to continue with the installation.

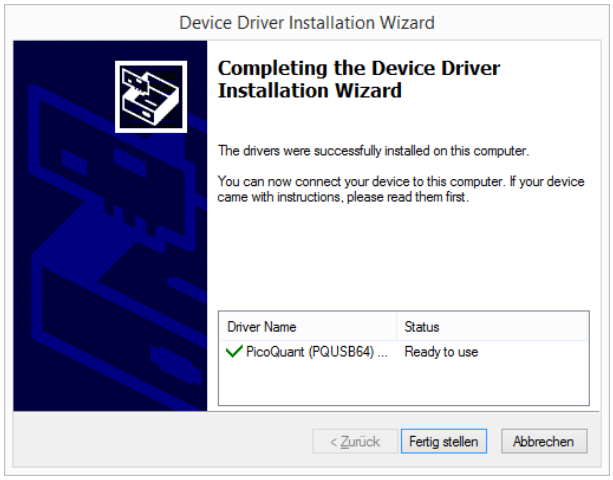

Fig. 13: PicoQuant Laser Driver GUI Setup Wizard - Driver completed

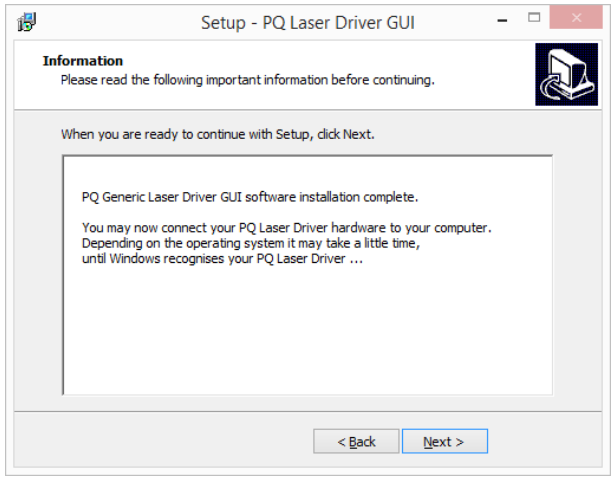

Fig. 14: PicoQuant Laser Driver GUI Setup Wizard - Software completed

Click *Next* when requested to complete the installation as shown in Fig. 13, Fig. 14.

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

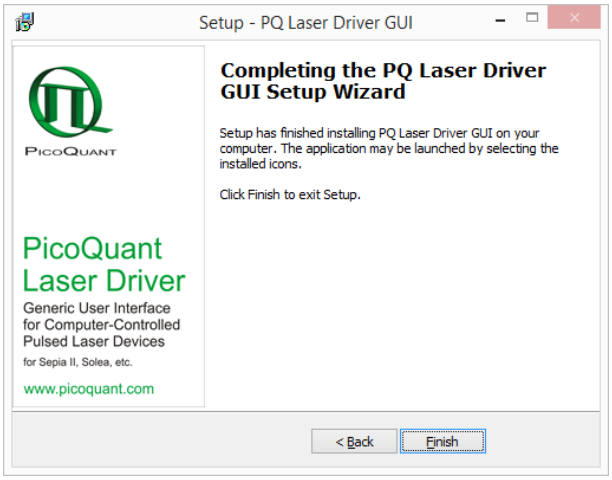

Fig. 15: PQ Laser Driver GUI Setup Wizard - Finish

Once the software is installed, the Solea can be turned on (see chapter 3.3 Starting the Solea). If the Solea is turned on for the first time, Windows will detect a new USB device and ask for its driver. Follow the dialog and guide Windows to look for the driver on the USB stick. Windows will then automatically install the necessary device drivers.

3.3. Starting the Solea

Before turning on the Solea, make sure that the power cord is connected to a suitable power outlet (100 to 250 VAC, 50/50 Hz, 3.5 A), that the USB cable is connected to the host computer, and that the control software is installed (see 3.2 Installing the Solea Software).

The laser key switch must be in the "*Laser Locked*" position before the Solea is turned on!

The main power switch is located on the back panel (see chapter 4.2 Interface / Back Plane).

After turning on the Solea, the laser will perform an initialization process, which takes about 30 seconds. Once this process is completed, as indicated by the LEDs "USB Init" and "USB start" (see chapter 4.1 Interface / Front Plane), the control software can be launched and the settings of the laser changed (see chapter 5 Software description).

Please allow a warm-up time of about 20 minutes before activating the laser using the laser key switch. This ensures an ideal stability of the optical output power. Activating the laser immediately after the Solea is powered on does, however, not cause any damage or quicker degradation to the Photonic Crystal Fiber.

After the warm-up period, the laser is activated by turning the laser key switch to the "ACTIVE" position.

Important Note:

In order to comply with Laser Class 4 / IV regulations, laser output will be internally blocked (hardware locked) if one of the following events occur:

- Power interruption during the operation of the Solea supercontinuum laser. Laser emission will **not** resume once power is restored.
- Interruption of the remote interlock circuit.
- Laser key switch is **not** in the *LASER LOCKED* position when the main power button is switched to the *ON* position (see chapter 4.1 Interface / Front Plane).
- Setting the laser soft-lock status in the GUI to *LOCKED*, i.e. laser emission will not be restored when switching the laser soft-lock back to the *UNLOCKED* state.

- Overheating of any internal laser diode due to too high external temperature is detected.

Once the hardware lock of the system has been triggered, the *LASER LOCKED* LED (see chapter 4.1 Interface / Front Plane) will permanently show red light, even when the laser key switch is in the *ACTIVE* position and the laser soft-lock in the GUI is in the *UNLOCKED* state (see chapter 5.1.3 Soft Locking and Unlocking of the Solea).

To unlock the system, a **manual reset** is needed. The **manual reset** is done by turning the laser key switch back into the *LASER LOCKED* position. Laser emission can then be reactivated by turning the laser key switch into the ACTIVE position and/or by deactivating the laser soft-lock in the GUI.

Please note that this safety feature is included in all Solea versions (even the ones specified as Laser Class 3b / IIIb products).

Make sure that the output of the delivery fiber is safely attached to the set-up before activating the laser!

4. Hardware Description

4.1. Interface / Front Plane

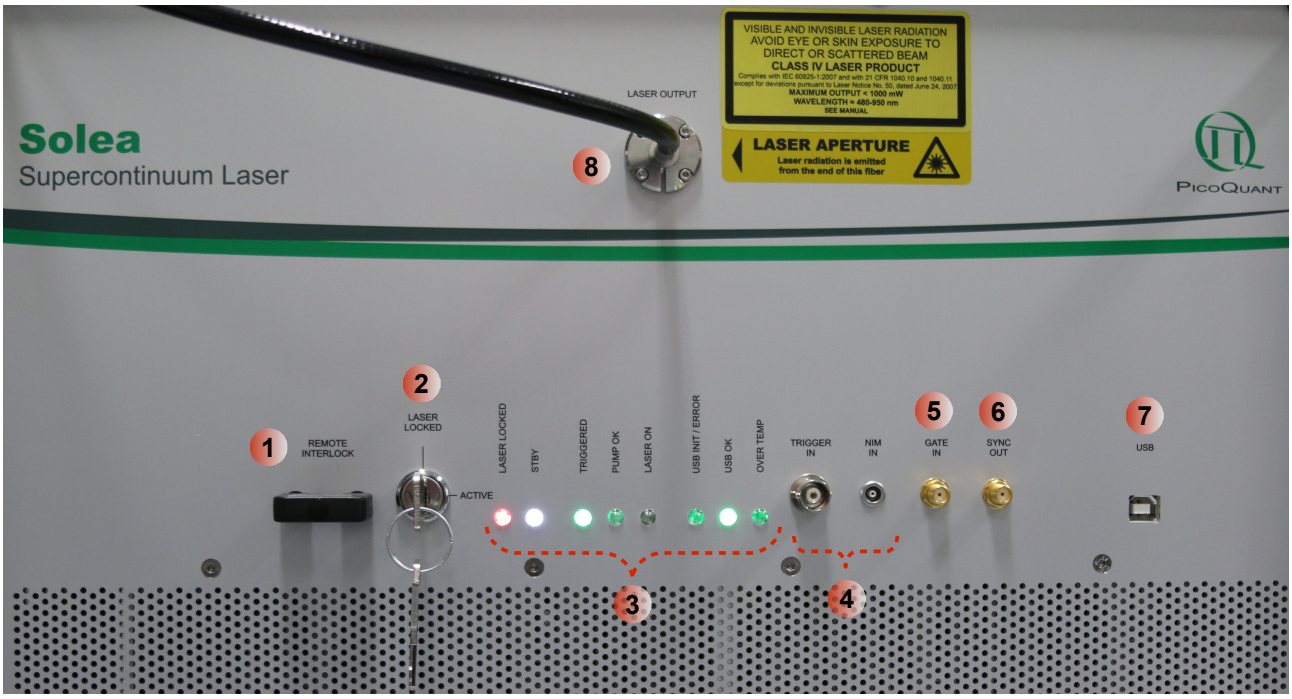

Fig. 16: Solea – front panel

1 Remote interlock connector. Refer to chapter 2.3 Remote Interlock Connectors and Manual Reset.

2 Key switch (laser activation switch). Turning the key to the **ACTIVE** position activates the laser. Power to the laser can be locked **OFF** by turning the key to the **LASER LOCKED** position and removing the key.

3 Status LED displays:

- **LASER LOCKED**: red LED. The LED stays ON as long as the laser is not emitting and switches OFF once the laser is emitting. The laser is emitting once all of the following conditions are met: Interlock key plugged, key switch set to **ACTIVE** and laser unlocked via the Solea software (see Chapter 5 Software description)
- **STBY**: white LED. Indicates that the laser is powered. If the LED is ON, protection goggles must be worn.
- **TRIGGERED**: green LED. The LED is ON if the laser is operated at a suited repetition rate. This is the case for all internal repetition rates and for external trigger signals with any repetition rate between 1 MHz and 40 MHz.
- **PUMP OK**: green LED. The LED is ON as long as the pump diodes of the fiber amplifier are active. This does **NOT** automatically mean that laser light is emitted!
- **LASER ON**: orange LED. The LED is ON as long as laser light is emitted.
- **USB INIT / ERROR**: red LED. The LED is blinking during the initialization process and turns OFF under normal operating conditions. In case of an error, the blinking sequence is coded and denotes the location of the problem.
- **USB OK**: green LED. The LED is blinking during the initialization process and stays ON under normal operating conditions. In case of an error, the LED turns OFF.

- **OVER TEMP**: red LED. The LED turns ON if one of the internal sensors indicates too high a temperature. If this LED is ON, no laser light can be emitted and the “LASER ON” LED is turned OFF.

4 Trigger inputs:

- **TRIGGER IN**: accepts a TTL signal; triggering is possible on either the rising or falling edge
- **NIM IN**: accepts a NIM signal (from, e.g., the PDL 828 “Sepia II” from PicoQuant)
- **NOTE:** The lowest possible repetition rate that can be realized by external triggering is 1 MHz. The Solea will not emit any light if an external trigger signal with a repetition rate below 1 MHz is supplied.

5 Gating input:

The gating function affects the triggering mechanism. It accepts TTL pulses and is effective when the Solea is being triggered from either the internal oscillator or from an external source. This gating function can perform a state transition within nanoseconds. Presuming a precise timing, it can switch between two laser pulses, even at high repetition rates. The number of laser pulses that can be gated depends on the repetition rate and is in the range of 3 to 8 pulses. If too many pulses are gated, the fiber amplifier switches off to prevent damage. It will be automatically switched on once the gating signal is disabled. Note that switching the amplifiers on is not instantaneous, but needs a few hundred milliseconds.

6 Synchronization output (NIM signal):

The synchronization output is generated from the driving signals of the seed laser. There is a delay between the output of the synchronization signal and the optical laser output, due to the fiber length used for amplification and supercontinuum generation. An additional small delay in the range of some 100 ps is also added due to dispersion depending on the selected wavelength. Please see the Laser Delivery Report at the end of this manual for reference.

7 USB connection to the host computer

8 Laser output / fiber coupler (delivery fiber)

4.2. Interface / Back Plane

Fig. 17: Solea – back panel

1 Power connector
2 Ground connector
3 Fan aperture
4 Remote control

Do not block the fan aperture. This might lead to laser instabilities or even damage due to overheating!

4.3. Solea – Working Principle

The Solea laser is based on a gain switched, picosecond pulsed seed laser diode along with a 3-stage ytterbium fiber amplifier and a Photonic Crystal Fiber (PCF) for supercontinuum generation (see Fig. 18).

The seed laser is based on a high-end, narrow line-width distributed feedback (DFB) laser diode emitting at 1064 nm. This seed diode is gain switched and can therefore be triggered externally.

The **patented** specific power management of the fiber amplifier's pump diodes ensures a constant laser pulse energy at the front of the PCF and thus a stable spectral shape of the supercontinuum for a wide range of internally or externally triggered repetition rates between 1 MHz and 40 MHz.

Two different modes of operation (ECO and BOOST) can be chosen depending on the needed level of laser output power and spectral range. In BOOST mode the Solea generates a higher output power and an extension of the supercontinuum spectral range in the into the blue. This, however, leads to a faster degradation of the PCF compared to the ECO mode (see chapter 5.1.7 Pump Control).

The wavelength selection is realized by a state-of-the-art tunable dielectric filter technology, allowing to select any central wavelength within the available spectral range with an adaptable spectral bandwidth. These filters provide not only very high extinction ratios (> 50 dB) but also extremely good transmission efficiencies (up to 85 %). Please note that the Solea White and SoleaR White do not feature the wavelength selector and can therefore only be used for supercontinuum emission.

The laser light is delivered by a polarization maintaining single mode fiber with End-Cap and FC/PC output connector. The fiber End-Cap reduces the power density at the fiber exit to avoid damage at the output facet of the polarization maintaining fiber (e.g., in case the unfiltered supercontinuum is emitted).

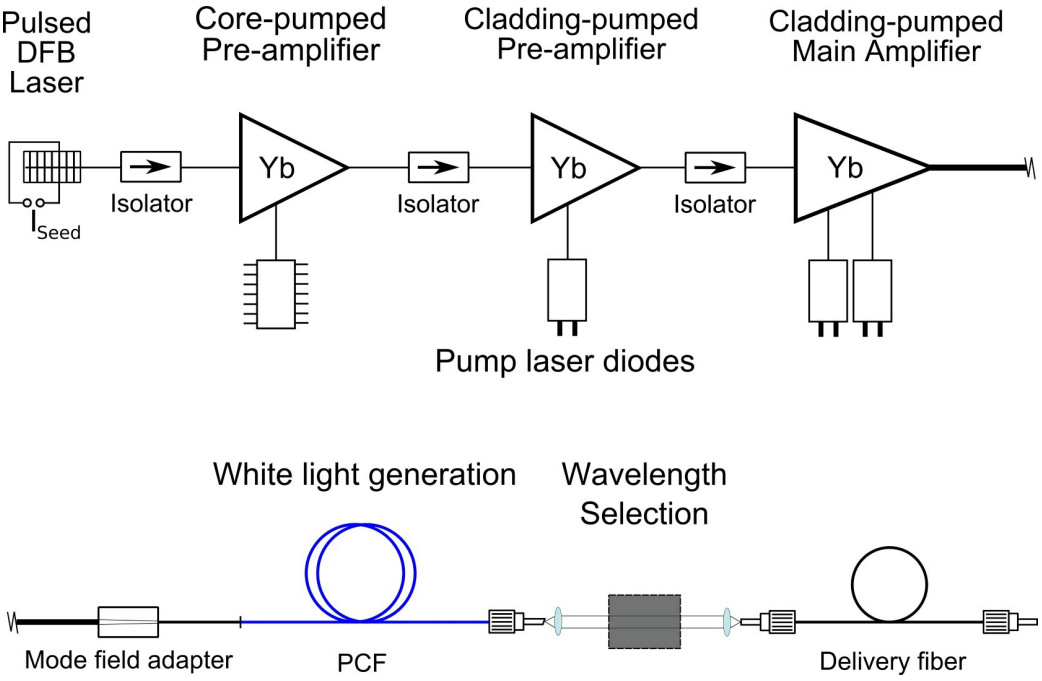

Fig. 18: Solea – working principle

5. Software description

5.1. Solea – Graphical User Interface (GUI)

The Solea must be turned on and initialization process completed before the software can be started!

The Solea GUI is available in three different **color schemes:** PicoQuant bright, PicoQuant dark, and a 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 the sake of better readability, all screen shots in this manual correspond to the PicoQuant bright color scheme.

During the software installation, the installer can optionally generate two distinct desktop short-cuts as well as two quick launch icons for the bright and dark schemes, respectively (see 3.2 Installing the Solea Software).

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

An overview of the GUI with all control elements is shown in Fig. 19 below.

Fig. 19: Solea GUI – Overview with 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 Solea or any other USB laser driver from PicoQuant such as the PDL 828 “Sepia II” or PPL 400 are connected to the same host computer.

A mouse click on the *Select Device* button will start a scan for other devices.

A modal dialogue with an *OK* and *Cancel* button presents a list box with the currently connected devices (Fig. 20). When opening the list box, all detected devices are listed by their serial number. The currently selected device is indicated with an asterisk “*”.

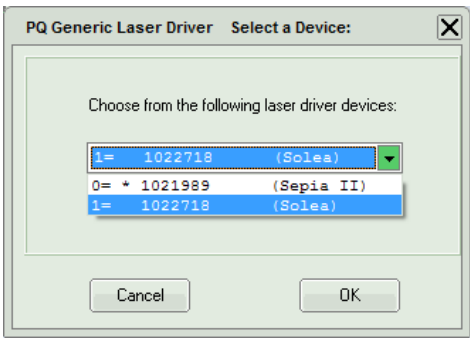

Fig. 20: Select device

Cancel return to the main window without making any changes.

OK change to the newly selected device.

Note that changing to a different laser driver might lead to changes in the GUI. The serial number of the currently selected laser is always displayed in the title bar of the software.

5.1.2. Discard / Apply 2

The *Apply* and *Discard* buttons must be used to confirm or cancel the configuration changes made in the GUI. In the example shown in Fig. 21, changes have been done in the wavelength selection part. The *Wavelength Selection* label and the *Apply* button are therefore highlighted (e.g., in orange) and remain highlighted until the changes are either applied or discarded.

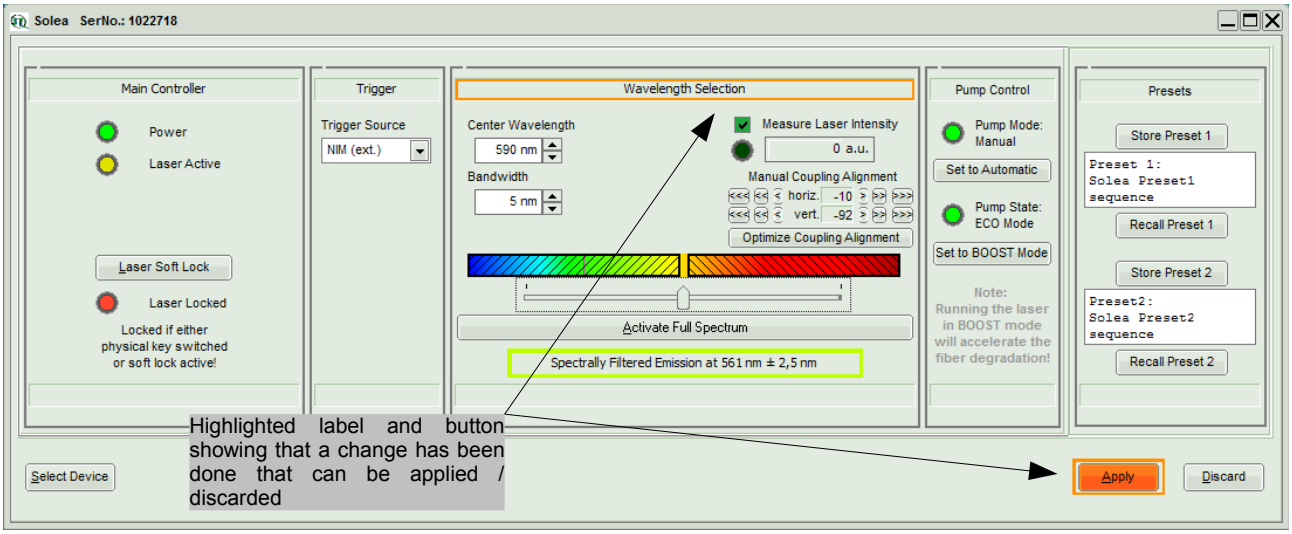

Fig. 21: Highlighted elements signal a recent change of parameters, which have to be applied or discarded.

5.1.3. Soft Locking and Unlocking of the Solea 3

The Solea can be locked (no laser light is emitted) and unlocked (laser light is emitted) not only with the hardware 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 Locked* state is recognizable in the software by the *Laser Locked* indicator turning bright red and the change of the button text to *Laser Soft Unlock* (see Fig. 23). In addition, the **LASER LOCKED** LED on the front panel of the Solea is turned ON.

The *Laser Unlocked* state is recognizable in the software by the *Laser Locked* indicator turning dark red and the change of the button text to *Laser Soft Lock* (see Fig. 22). In addition, the **LASER LOCKED** LED on the front panel of the Solea is turned OFF.

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 Solea (see chapter 4.1 Interface / Front Plane).

Also note that activating the *Laser Soft Lock* mode will trigger the hardware lock of the Solea. Thus, in order to restore laser emission after pressing the *Laser Soft Lock* button, you have to turn the hardware lock key on the front panel first to the *LASER LOCKED* and then to the *ACTIVE* position. Refer also to Chapter 2.3 Remote Interlock Connectors and Manual Reset for further information about the hardware lock and manual reset functions.

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

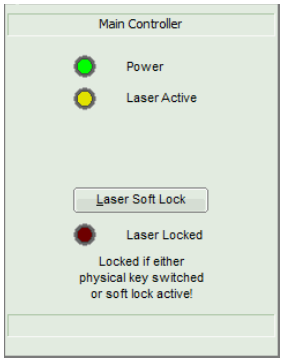

Fig. 22: Laser unlocked

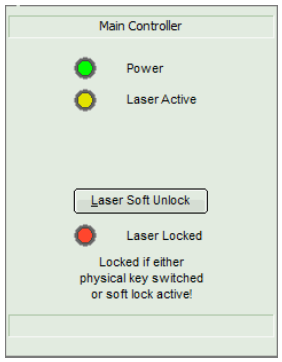

Fig. 23: Laser locked

5.1.4. Setting the Repetition Rate 4

The controls and current state of the repetition rate can be found in the frame labeled *Trigger*. The repetition rate can be derived from either the internal oscillator or an external trigger signal (NIM or TTL).

Setting the repetition rate or trigger type is possible via the drop-down menu labeled *Trigger Source* (see Fig. 24) to:

- five user selectable, internal repetition rates between 2.5 MHz and 40 MHz
- external triggering via a NIM signal (labeled *NIM (ext.)*). In this case a NIM signal must be connected to the NIM input on the front panel of the Solea (see chapter 4.1 Interface / Front Plane)
- external triggering via a TTL signal, either on the rising edge (labeled *rising (ext.)*) or falling edge (labeled *falling (ext.)*). In both cases, an additional input field is shown that allows to set the trigger level (see Fig. 25). In this case a TTL signal must be connected to the TTL input on the front panel of the Solea (see chapter 4.1 Interface / Front Plane)
- **NOTE**: the lowest possible repetition rate that can be achieved by external triggering is 1 MHz. The Solea will not emit any light if an external trigger rate below 1 MHz is supplied.

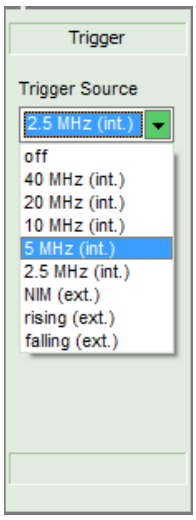

Fig. 24: Selecting the trigger source

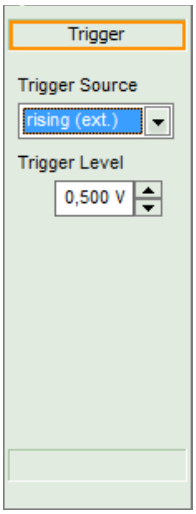

Fig. 25: Setting the trigger level

5.1.5. Wavelength Selection 5

Wavelength selection is available only on the Solea and SoleaR devices. Device versions labeled with the suffix “White” are not equipped with an emission wavelength selector module and therefore do not allow for wavelength selection.

The controls for the wavelength selector are located inside the frame labeled *Wavelength Selection* (see Fig. 26). The wavelength selector permits to set the central emission wavelength as well as the spectral bandwidth of the emission. Alternatively, the wavelength selector can also be bypassed, giving access to the available supercontinuum emission of the Solea. There are also controls allowing to optimize the laser output by adjusting the fiber coupling through motorized beam adjustment elements.

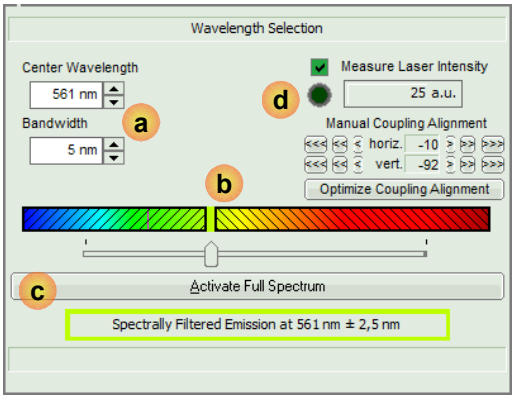

Fig. 26: Wavelength selection controls

a The central wavelength and bandwidth can be set within the possible range by two corresponding spin edit fields. Alternatively, the slider below the rainbow can be used.

b The slider located below a graphical representation of a rainbow can also be used to set the central emission wavelength (but not the bandwidth!). The value can be changed with nanometer precision by dragging the cursor below the rainbow or by clicking at any position inside the rainbow. Each mouse click will move the central emission wavelength by 25 nm in the corresponding direction.

c The button located at the bottom part of the frame is used to activate or bypass the wavelength selector.

If the wavelength selector is activated, the button text reads *Activate Full Spectrum* and the text area below the button shows the currently selected values for the central wavelength and bandwidth. The text area is highlighted in the color of the current central emission wavelength (see Fig. 27).

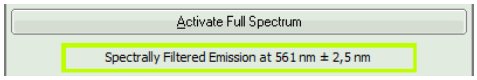

Fig. 27: Wavelength selector is active

If the wavelength selector is bypassed, the graphical representation of the rainbow disappears, the button text now shows *Activate Wavelength Selection* and the text area below the button shows *Continuous Broadband Emission ("White"),* highlighted in white (see Fig. 28)

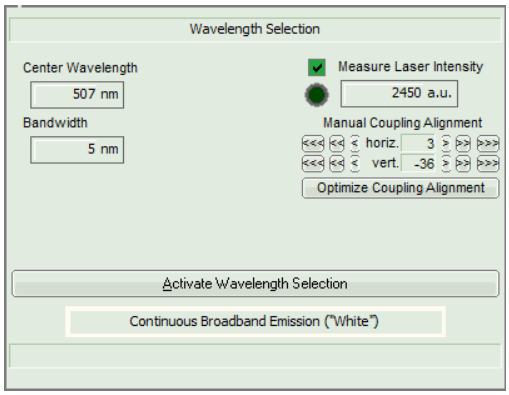

Fig. 28: Wavelength selector is bypassed

d Coupling alignment

The wavelength selector includes two motorized elements that can be used to adjust the laser beam position vertically or horizontally in order to maximize laser power output by optimizing the light coupling into the delivery fiber. These elements are necessary because the optical filters included in the wavelength selector introduce a slight beam deflection depending on the selected central wavelength. When changing the central emission wavelength, the elements are set to their optimum positions, determined during the production of the Solea. In some cases, e. g., at a different ambient temperature, it might, however, be necessary to slightly optimize their position and thus the optical output power.

To facilitate this procedure, the wavelength selector includes an integrated photodiode, which provides a relative measurement of the optical power coupled into the delivery fiber. The reading on this photodiode is therefore directly related to the coupling efficiency, i. e. maximizing this reading also maximizes the coupling efficiency.

The measurement is activated through ticking the check box labeled *Measure Laser Intensity*. If activated, a new measurement is performed every 4-5 seconds as well as immediately after any adjustment to the beam position. A new measurement is indicated by a green blinking indicator.

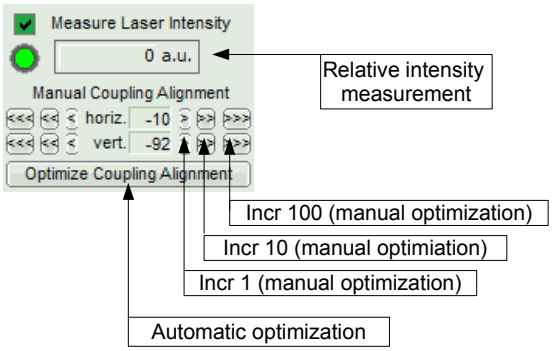

Fig. 29: Output power optimization using the integrated beam adjustment elements and power diode

The adjustment elements can move a full 180° in 800 discrete, arbitrary steps. Position values range from -400 to 400. Position 0 corresponds to a position perpendicular to the incident beam. Positions -400 and +400 correspond to the two parallel positions relative to laser beam. The position of the adjustment elements can be incremented in 1, 10 or 100 motor steps (see Fig. 29)

The vertical adjustment of the beam position allows to compensate for the beam offset generated by the wavelength selector and can therefore be optimized after a change of the central emission wavelength. The position value should be in the range between -100 and +100. Any position value exceeding +/- 150 corresponds to a complete misalignment of the beam and a near zero coupling efficiency in the delivery fiber. Should this be the case, please contact PicoQuant for support.

The horizontal adjustment of the beam position usually has only minor influence on the coupling efficiency. It can, however, be useful in order to compensate slight misalignments related to mechanical stress, e.g., after transport of the unit. The position value should lie in the range of -10 and +10. Any position value exceeding +/- 50 corresponds to a complete misalignment of the beam and a near zero coupling efficiency in the delivery fiber. Should this be the case, please contact PicoQuant for support.

The coupling optimization can be done either manually or automatically. To start the automatic optimization, click on the button labeled *Optimize Coupling Alignment*. A warning windows appears (Fig. 30) indicating that the automatic optimization can take some time, as the adjustment element are driven step by step on different positions to locate their optimum position.

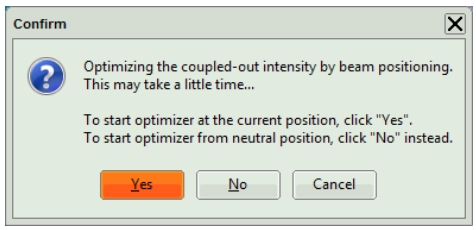

Fig. 30: Automatic optimization - Warning

5.1.6. Presets 6

Two working configurations can be saved and recalled in the frame labeled *Presets*.

Each preset stores all working conditions including:

- Trigger source (internal or external input signal)
- Central emission wavelength
- Bandwidth
- Power optimization (position of the beam adjustment elements for the given central wavelength)

Fig. 31: Save a configuration

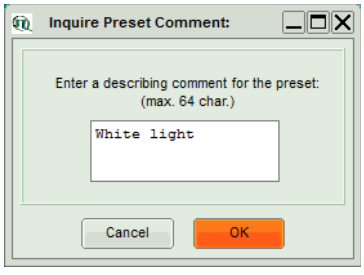

Fig. 32: Edit comment for a preset

The currently applied configuration can be saved by clicking on the *Store Preset 1* or *Store Preset 2* button (see Fig. 31). A pop up window gives the possibility to include a short comment to each stored configuration (see Fig. 32).

A stored configuration can be recalled by simply clicking on the button labeled *Recall Preset 1* or *Recall Preset 2*.

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

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

5.1.7. Pump Control 7

As mentioned in chapter 1.3 Pump Diode Management – Modes of Operation, the Solea can be operated in two modes, ECO and BOOST, where different amounts of power are delivered to the fiber amplifiers.

Control of the operation mode can be done either automatically or manually. Switching between the automatic and the manual pump mode is possible by clicking on the button labeled *Set to Manual* or *Set to Automatic* in the *Pump Control* interface.

Automatic Pump Mode

The automatic pump mode is indicated by an orange LED-like indicator in the upper part of the *Pump Control* interface (See Fig. 33 and Fig. 34).

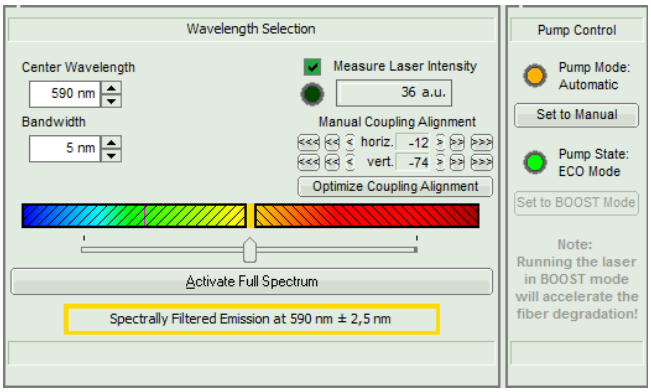

Fig. 33: Automatic / ECO Mode

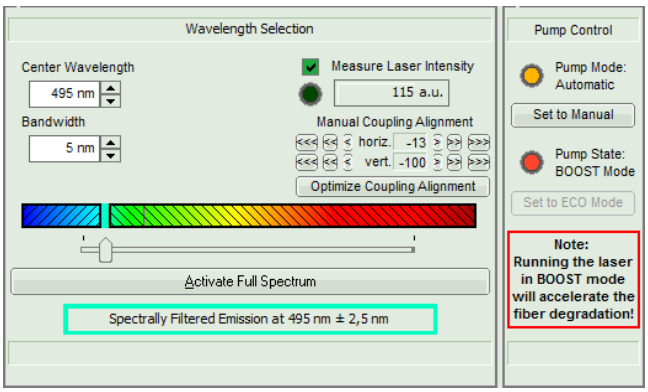

Fig. 34: Automatic / BOOST Mode

In automatic pump mode, the Solea operates in ECO mode as long as the wavelength selector is either bypassed or set to any wavelength between 525 nm and 700 nm (or 900 nm in the case of the SoleaR). The ECO mode is indicated by a green LED (see Fig. 33, below the *Set to Manual* button).

The operation mode is automatically switched to BOOST mode if the wavelength selector is set to a wavelength shorter than 525 nm. This wavelength threshold is also indicated in the rainbow graphic by a vertical line. The BOOST mode is indicated by a red LED-like indicator and a warning note highlighted in red concerning accelerated fiber degradation (see Fig. 34).

Manual Pump Mode

The manual pump mode is indicated by the a green LED-like indicator in the upper part of the *Pump Control* interface (see Fig. 35 and Fig. 36).

In manual pump mode, it is possible to set the Solea to ECO or BOOST mode independently from the settings of the wavelength selector. This gives for example the possibility to switch the laser into BOOST mode for emission wavelengths greater than 525 nm, should a higher level of optical power be required (see Fig. 35)

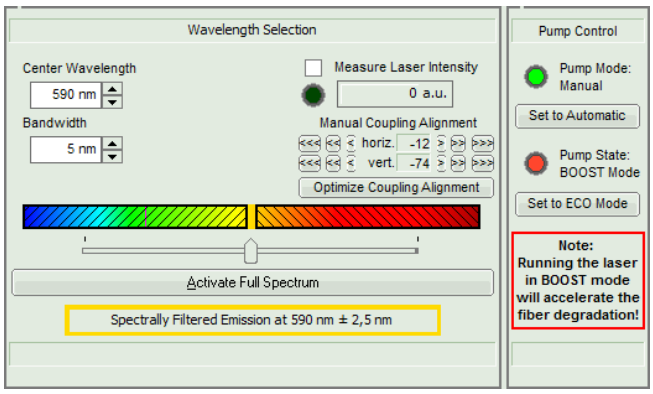

Fig. 35: Manual yellow BOOST

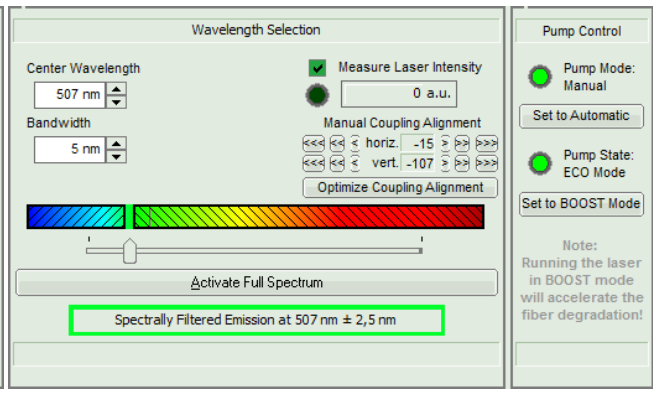

Fig. 36: Manual blue ECO – Low power!

The manual pump mode allows any combination of settings, including inappropriate ones, such as running in ECO mode with a central wavelength below 525 nm. This can lead to very low or even no output power (see Fig. 36)!

5.1.8. About / Request Support 8

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

For every support request, its is recommend to copy the entire information into the Windows clipboard by clicking on the button labeled *Copy Support Infos* (see Fig. 37). Paste these into an e-mail and send it to info@picoquant.com.

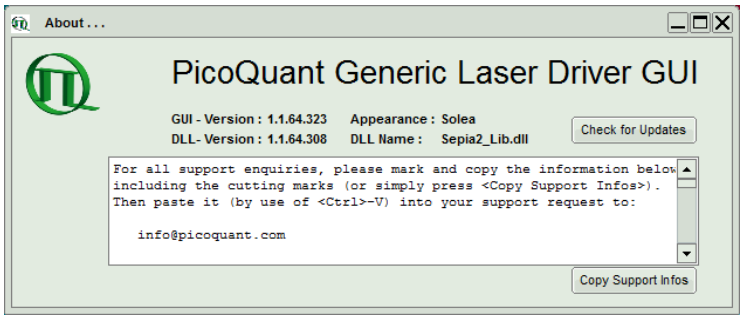

Fig. 37: The “About” window includes extended information about the status of the Solea

It is also possible to search for possible software updates by clicking on the button labeled *Check for Updates* (see Fig. 37). If an update is available, a download link to the latest version will be provided.

6. Trouble Shooting, Tips and Tricks

6.1. Prolonging the Lifetime of the Photonic Crystal Fiber (PCF)

A well known issue of supercontinuum lasers is the degradation of the PCF leading to decreased optical output power. To prolong the lifetime of the PCF, it is essential to only activate the laser when its emission is needed. If laser emission is not needed, set the laser into the “Locked” mode by either turning the key switch on the front panel (see chapter 4.1 Interface / Front Plane) or by clicking on the corresponding button in the GUI panel of the software (see chapter 5.1.3 Soft Locking and Unlocking of the Solea).

The second factor influencing the PCF lifetime is the operation mode. For standard operation, it is recommend to use the Solea in ECO mode. The spectral emission of the supercontinuum in ECO mode starts at 525 nm, meaning that it nicely fits the green / orange gap where no direct emitting laser diodes are available.

The BOOST mode can be used when more power or shorter wavelengths are needed. In BOOST mode the amount of power delivered to the fiber amplifier is increased, which results in an increase of the overall optical power of the supercontinuum and the extension of its spectral range down to 480 nm. However, the degradation of the fiber is much faster in BOOST mode. It is therefore strongly recommended to **use the BOOST mode only if strictly necessary**. Users that need to work mostly at wavelengths of 510 nm, 500 nm or 485 nm can alternatively use the available and affordable pulsed diode lasers from PicoQuant (LDH Series).

Predicting the lifetime of the PCF is difficult because it strongly depends on the mode of operation, intensity level of the pump diode, and repetition rate. However, endurance tests lead to the estimation that the overall output power of a Solea running in ECO mode at 40 MHz repetition rate decreases by about 30 % after 1000 hours and by about 50 % after 2000 hours. Similar tests in BOOST mode show a decrease of up to 50 % within 150 hours.

6.2. External Triggering beyond 40 MHz

The Solea can operate at any repetition rate between 1 and 40 MHz via external triggering.

Should the repetition rate of the external trigger signal be higher than 40 MHz, the Solea will scale it down to the closest acceptable value. For example, if the Solea is externally triggered at a repetition rate of 80 MHz using, e.g., a trigger signal from a Titanium:Sapphire laser, the repetition rate will be divided by a factor of two, yielding an effective pulse repetition rate of 40 MHz.

The highest repetition rate at which the Solea can be externally triggered is 100 MHz.

6.3. Power Stability

Please allow a laser warm-up time of about 20 minutes before activating the laser using the laser key switch. This ensures an ideal stability of the optical output power.

If the laser is unlocked via the software GUI panel, please also allow a warm-up period between 3 and 5 minutes to ensure stability of the optical output power.

6.4. USB Connection Problem

If the USB connection between the Solea and the computer is interrupted, a warning message appears in the slot labeled *Main Controller* as shown in Fig. 38. In this case, please check the USB connection and try to reconnect your device either by restarting the software or by re-selecting the device through the *Select Device* function (see chapter 5.1.1 Select Device).

Fig. 38: USB connection lost

6.5. Amplifier Failure

The optical power generated by the Solea is continuously monitored using an internal photodetector. Should a sudden, critical drop in power be detected, the laser will automatically shut down and the error message *Amplifier failure! Will* appear in the bottom part of the slot labeled *Pump Control* (see Fig. 39). If such an error message appears, please contact PicoQuant for support.

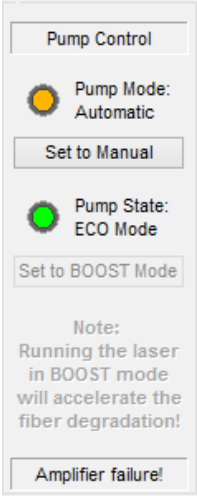

Fig. 39: Amplifier Failure

6.6. Packaging the Solea

Warning! **Due to the heavy weight of the Solea (approx. 32 kg), the packing / unpacking procedure requires at least two persons. Attempting to perform the procedure alone might lead to injury!**

Should you need to ship the Solea to PicoQuant for inspection / repairs or need to transport the instrument, you should use the original packaging material (or equivalent). Follow the procedure detailed here to ensure the best possible protection of the instrument during the shipping process.

1. Start by opening the crate and removing the packaging material until only the two bottom foam brackets are present, as shown in Fig. 40.

   Please note that the bracket side with the square corner corresponds to the front (i. e., front panel), while the tapered corner corresponds to the back of the Solea (back panel). Also the bottom brackets have a hole in the middle, while the top brackets don't. Make sure you don´t mix up the two types of brackets

   The power plug and the USB cable can be stowed in the hole of the brackets.

Fig. 40: Orientation of the bottom foam brackets in the box

2. Leave the optical fiber connected to fiber coupler. Make sure that the other end of the fiber is capped and loosely rolled-up. Place the rolled fiber into an air bubble wrap bag for added protection.

   Do not bend the fiber too strongly! Doing so will break it.

   Carefully lower the Solea into the lower foam brackets (see fig. 41) and keep the rolled-up fiber on top of the instrument.

Fig. 41: Lowering the Solea into the bottom styrofoam brackets

3. The manual and other documents, wrapped in an air bubble bag, can be placed on top of the Solea and next to the optical fiber, as shown in fig. 42. Make sure that nothing clips over the sides of the Solea.

Fig. 42: Placing the manual and optical fiber

4. Place now the two top foam brackets on top of the Solea and push them gently down.

   Please note that, once again, the square corner fits to the front of the Solea, while the tapered corner goes to the back.

   Also, the top brackets have no hole in the middle.

Fig. 43: Placing the top foam brackets

5. Fill up the remaining empty space at the top of the wooden shipping crate with styrofoam chips.

   These chips should be contained in a plastic bag to avoid having them spread out over the inside of the box.

Fig. 44: Filling up the empty space with sytrofoam chips

6. Now close the shipping box by placing its lid on, as shown in fig. 45.

   Make sure that the metal noses are straight to fit through the corresponding slits.

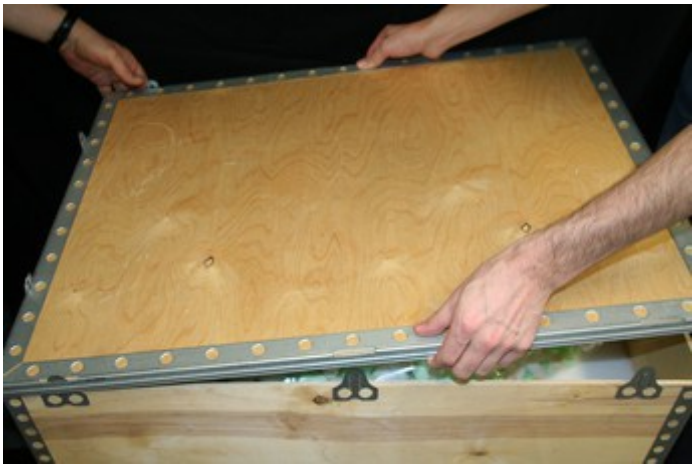

Fig. 45: Placing the lid on the shipping box

7. Secure the lid of the shipping box by bending down the metal nose with a hammer, as shown in fig. 46.

   Be careful during this step and avoid hitting the sides or lid of the shipping box.

Fig. 46: Securing the lid of the shipping box

8. Should you need to open the shipping box, use a flat head screwdriver to pull up the metal noses securing the lid.

   Once all noses have been lifted, the lid can be simply pulled from the box.

Fig. 47: Removing the lid of the shipping box

9. Finalize the package by sealing the box edges with adhesive tape, adding warning labels (caution fragile, protect from humidity) and schockwatches. The box should now look like in fig. 48.

   It is a good idea to additionally secure the lid with pull wires as shown in fig. 48. Do not forget to affix the proper shipping addresses and documents on the boxes exterior.

Fig. 48: Adding warning labels, schockwatches, and sealing with adhesive tape

7. Technical Data / Specifications

Mainframe

Power supply..... 100 to 250 VAC, 50/50 Hz, max 375 Watt

Dimensions..... 465 x 425 x 285 mm (W x D x H)

Weight..... 32.6 kg

Oscillator

Oscillator type..... crystal locked

Base frequency..... 40 MHz

Divider..... 1, 2, 4, 8, 16

Repetition rate..... divided internal clock frequency or externally triggered frequency

External NIM trigger input

Connector type..... NIM-CAMAC

Amplitude..... -2 to +1 V (maximum limits)

Trigger level..... -0.4 V

Range of repetition rates..... up to 41 MHz non prescaled, 41 up to 100 MHz prescaled

External TTL trigger input

Connector type ..... BNC

Amplitude..... -5 to +5 V (maximum limits)

Trigger level..... adjustable between -1 and +1 V

Range of repetition rates..... up to 41 MHz non prescaled, 41 up to 100 MHz prescaled

Fast gate

Connector type..... SMA (female)

Amplitude ..... -1 to +6 V (maximum limits)

Trigger level ..... < 1 V pulse disabled, > 2.5 V pulse enabled

Synchronization output

Connector..... SMA (female)

Amplitude..... < -800 mV into 50 Ω (NIM)

Timing..... synchronized to the repetition rate

Optical Output

Spectral range (-3 dB bandwidth):

Solea and Solea White:

..... 525 – 700 nm (ECO Mode)

..... 480 – 700 nm (BOOST Mode)

SoleaR and SoleaR White:

..... 525 – 900 nm (ECO Mode)

..... 480 – 900 nm (BOOST Mode)

Pulse width..... min. 90 ps; typ. 150 ps; max. 230 ps

Average Output Power at 40 MHz:
Solea and Solea White:

.....> 100 mW (ECO Mode)

.....> 250 mW (BOOST Mode)

SoleaR and SoleaR White:
.....> 250 mW (ECO Mode)

.....> 750 mW (BOOST Mode)

Output..... polarization maintaining single mode fiber with high power FC/PC connector
..... (End-Cap), length 3 m

Stability..... 3 % rms

Delay relative to.....please refer to the Laser Delivery Report
synchronization output

Output after the wavelength selector (not included in Solea White and SoleaR White)

Bandwidth..... 3 - 15 nm or fully available supercontinuum

Average output power @ 40 MHz repetition rate:

..... 1.0 mW (ECO mode, 5 nm bandwidth)

..... 2.5 mW (ECO mode, 5 nm bandwidth)

Computer

Operating System.....Windows™ 7 / 8 / 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, Fig. 37). In case the Solea 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.

Please refer also to chapter 6.6 for an illustrated guide on how to properly pack the Solea using the original packaging material.

8.2. PicoQuant 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

11.1. Abbreviations

BNC	British Naval Connector or Bayonet Nut Connector or Bayonet Neill Concelman
CAMAC	Corporations and Markets Advisory Committee
DFB	Distributed Feedback
DLL	Dynamic Link Library
FC/PC	Ferrule Connector or Fiber Channel / Physical Contact
FWHM	Full Width at Half Maximum
IEC	International Electrotechnical Commission
IRF	Instrument Response Function
LED	Light Emitting Diode
NIM	Nuclear Instrumentation Methods
OD	Optical Density
GUI	Graphic User Interface
PCF	Photonic Crystal Fiber
PM	Polarization Maintaining (fiber type)
RMA	Return Mechandise Authorization
SMA	Sub-Miniature version A (connector type)
TCSPC	Time-Correlated Single Photon Counting
Ti:Sa	Titanium-Sapphire
TTL	Transistor-Transistor Logic
USB	Universal Serial Bus
UV	Ultra-violet
VIS	Visible
WEEE	Waste Electrical and Electronic Equipment

11.2. 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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