A P E

PULSE SELECTOR

Manual

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1. Introduction

Mode-locked lasers which are capable of generating very short laser pulses (e.g. picosecond or femtosecond pulses) have pulse repetition rates corresponding to the round trip time of the light in the laser cavity. This frequency is in the range around 80 MHz for many ion, dye and tunable solid state lasers used in scientific applications. The frequency corresponds to a pulse separation time of 12.5 ns. For a number of applications like measurement of longer fluorescence decay times or some pump and probe experiments it is desirable, however, to have a lower repetition rate. This can be achieved with different methods acting inside or outside the laser cavity.

The APE PulseSelect Dual is well suited for pulse selection of mode-locked lasers with repetition rates between 70 and 85 MHz (to be specified at time of order) outside the laser cavity. Its function is based on the acoustooptic effect. In a suitable crystal (e.g. Fused Silica, TeO2) a modulation of density and thus of refractive index is introduced by an acoustic signal with high frequency of about 400 MHz. The index modulation acts as a three-dimensional optical grating on a laser beam passing the crystal and leads to a diffraction of the beam. The acoustic wave inside the crystal is generated by applying an electrical RF signal to a piezoelectric transducer cemented on the crystal. By using short RF pulses single laser pulses can be selected from the pulse train and deflected to the first diffraction order. So they are separated from the other pulses and are available for use in the experiment. However, in all pulse selectors based on the acoustooptic effect, both the efficiency of diffraction into the first order and the contrast ratio between the selected pulse and the non-selected ones, especially the very next one, are limited. In the APE PulseSelect Dual two synchronized modulator stages are set up in series to further increase the contrast ratio compared to conventional single stage pulse pickers. On the other hand this is at expense of overall diffraction efficiency.

The PulseSelect Dual consists of the optics module and the driver and control electronics module. The optics module contains the two Bragg cells as the most important parts which select single pulses from the laser beam based on the acoustooptical effect. Furthermore it contains focusing and collimating mirrors for each stage to form a beam waist inside the Bragg cells, and beam stops to reject the zero order beams.

The driver electronics provide the modulated RF signals for the Bragg cells with a carrier frequency equal to the fivefold of the laser repetition rate and an output power of up to about 17.5 W (peak). There are two RF channels, one for each Bragg cell, which are driven by a common seed frequency signal from the laser and thus are synchronized to the laser pulses.

The standard range for the division ratio of the laser repetition rate is 1:20 to 1:5000 (optionally 1:10 to 1:5000 or 1:2 to 1:260000). For synchronization the user must provide a seed signal with the laser repetition rate (for instance from a fast photodiode) and with an amplitude of 100 mV ... 1.25 V at 50 Ω. Instead of using the internal frequency divider single pulses can be selected by external triggering the PulseSelect with a TTL signal at the 50 Ω external trigger input. Also in this case the „SEED“ input signal is required.

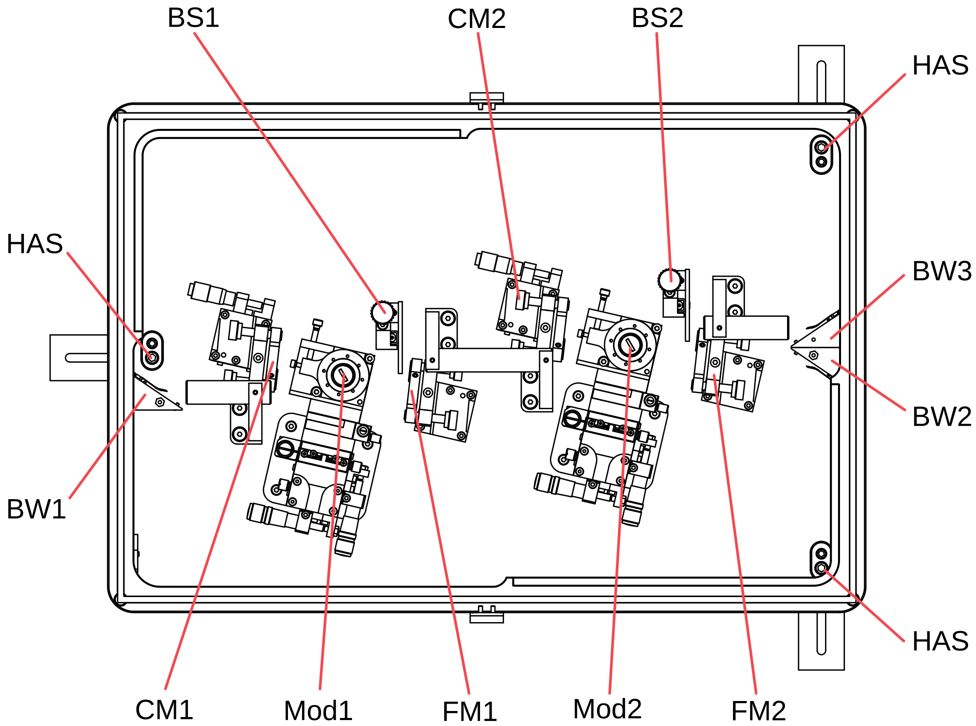
Depending on the used modulator type (in dependence on the laser system and the application) diffraction efficiencies of > 36 % (at 800 nm) can be achieved.

2. Optics

Figure 1 shows the elements of the PulseSelect Dual optics in top view. The optics set up is designed for horizontal polarization of the laser. The beam travels through the input Brewster window BW1 onto the first focusing mirror FH1. From there it is reflected and focused into modulator Mod1, which is arranged in Brewster angle to the beam.

By applying the modulated RF signal from the driver electronics to the Modulator a part of the beam (selected pulses) will be deflected into the 1st diffraction order. The zero order and first order beam are recollimated by the collimating mirror CM1 and directed to the second focusing mirror FM2. The zero order beam can be blocked by the adjustable beam stop BS1.

From there it is reflected and focused into modulator M2, which is arranged in Brewster angle to the beam. By applying the modulated RF signal from the driver electronics to the Modulator a part of the beam (selected pulses) will be deflected into the 1st diffraction order. If RF signal from modulator Mod1 is on and beam stop BS1 blocks the zero order beam of modulator Mod1, only selected pulses arrive at modulator Mod2. In this case the major part of first order beam of modulator Mod1 should be deflected into 1st diffraction order by modulator M2. The zero order and first order beam are recollimated by the collimating mirror CM2. The zero order beam can be blocked by the adjustable beam stop BS2.



FM1	-	Focusing mirror 1
FM2	-	Focusing mirror 2
CM1	-	Collimating mirror 1
CM2	-	Collimating mirror 2
Mod1	-	Modulator 1
Mod2	-	Modulator 2
BS1	-	Beam stop 1
BS2	-	Beam stop 2
BW1	-	Beam input Brewster window
BW2	-	Beam output Brewster window for single stage operation
BW3	-	Beam output Brewster window for dual stage operation
HAS	-	Height adjustment screws

Fig. 1 Optics module - top view

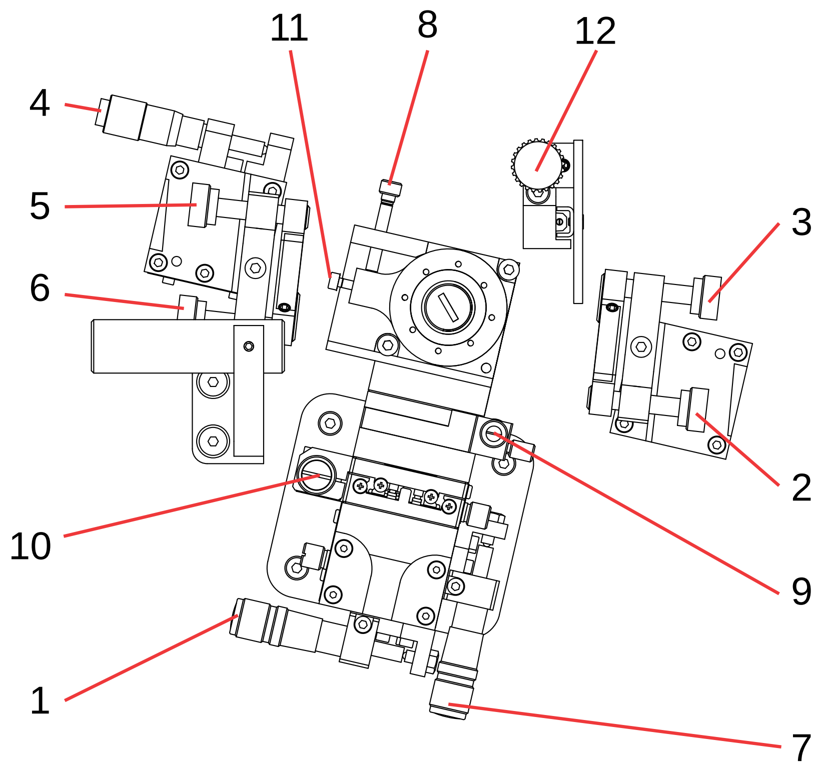
3. Installation and Basic Adjustment

Warning! All adjustments should first be done with attenuated laser beam! Pay attention to the safety rules according to the class of your laser! The installation and adjustment should only be done by personnel skilled in the handling of optics and lasers!

If the modulators are not installed in the optics module or you need to change the modulator, refer to appendix 1 for instructions.

Warning! Pay attention to the maximum laser power permitted for the respective modulator type:

Fused Silica (SiO_2):	4500 mW
Tellurium Oxide (TeO_2):	500 mW



1	-	Modulator focusing adjustment screw, horizontal position
2	-	Focusing mirror, vertical tilt control
3	-	Focusing mirror, horizontal tilt control
4	-	Collimating mirror, horizontal position adjustment screw
5	-	Collimating mirror, vertical tilt control
6	-	Collimating mirror, horizontal tilt control
7	-	Modulator, horizontal position adjustment screw
8	-	Modulator, Brewster angle adjustment screw
9	-	Modulator, Bragg angle control
10	-	Modulator, vertical position adjustment screw
11	-	Modulator, rough Brewster angle adjustment lock screw
12	-	Beam stop adjustment screw

Fig. 2 Optics - adjustment controls

- Before installation all optical parts (brewster windows, mirrors, modulator crystals) should be cleaned if nessesary using common optics cleaning techniques and methanol as detergent.
  Make sure that the crystal is not connected to RF while cleaning.
- At the beginning of the basic adjustment described in the following paragraphs the modulators have to be driven out of the beam path by using the vertical position adjustment screw [10]. The Brewster angle adjustment screws of the Bragg cell holders [8] should be set to 0°. Set the horizontal position adjustment screws for the focusing and collimating mirrors [1, 4] to a middle position.
- Place the PulseSelect optics module in front of the laser. Depending on the laser beam parameters it can be of advantage to place the PulseSelect at a distance of about 1.0 ... 1.5 m from the laser to achieve best performance. The laser beam must enter the optics module in the centre of the input aperture. Use the height adjustment screws ([HAS] Fig.1) of the optics module to fit it to the height of the beam. Afterwards the beam should hit focusing mirror FM1 centered. Once reached this position the optics module should be fixed on the table with the clamps.
- Adjust the beam to fall onto the collimating mirror CM1 at middle height and about 1 mm right from centre. Use the tilt controls of the focusing mirror FM1!

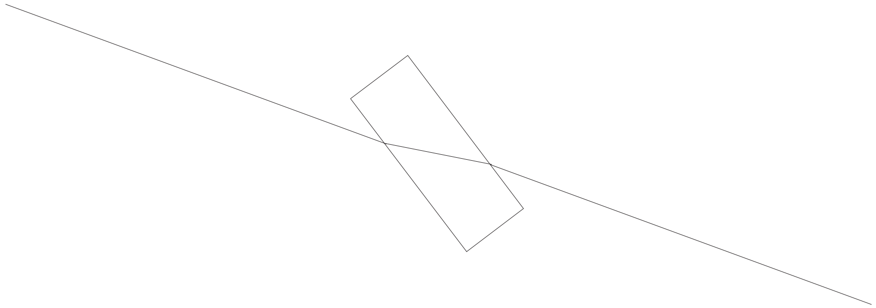


Fig. 3 Beam path through the modulator

- Now the modulator crystal can be driven into the beam path with the vertical position adjustment screw ([10] Fig. 2). While doing this, the horizontal position adjustment screw [7] should be in a middle position. Now the beam should hit the collimating mirror CM1 centered. Use the tilt controls of the focusing mirror FM1 to correct for this!
- The laser beam should pass the modulator crystal through its center (see Fig. 3). Check the beam path inside the modulator crystal (with an IR-viewer, if necessary) and correct the horizontal crystal position ([7] Fig.2).
- Direction and collimation of the output beam can be adjusted with the tilt controls ([5,6] Fig. 2) and horizontal position control ([4] Fig. 2) of the collimating mirror CM1.

The description of the basic alignment of the first modulator stage given above applies to the second modulator stage accordingly. Use the tilt controls of collimating mirror CM1 to direct the beam centered to the focusing mirror FM2. Make sure that the beam stop BS1 gives way for the beam. After having passed the modulator Mod2 and the collimating mirror CM2 the beam should leave the PulseSelect through the centre of Brewster window BW3 collimated and parallel to the optical table.

4. Driver Electronics

Fig. 4 and 5 show the front and rear panel of the driver electronics module with controls and signal inputs and outputs. On the left top of the front panel there is a LCD graphic display.

Fig. 4 Driver electronice unit front panel

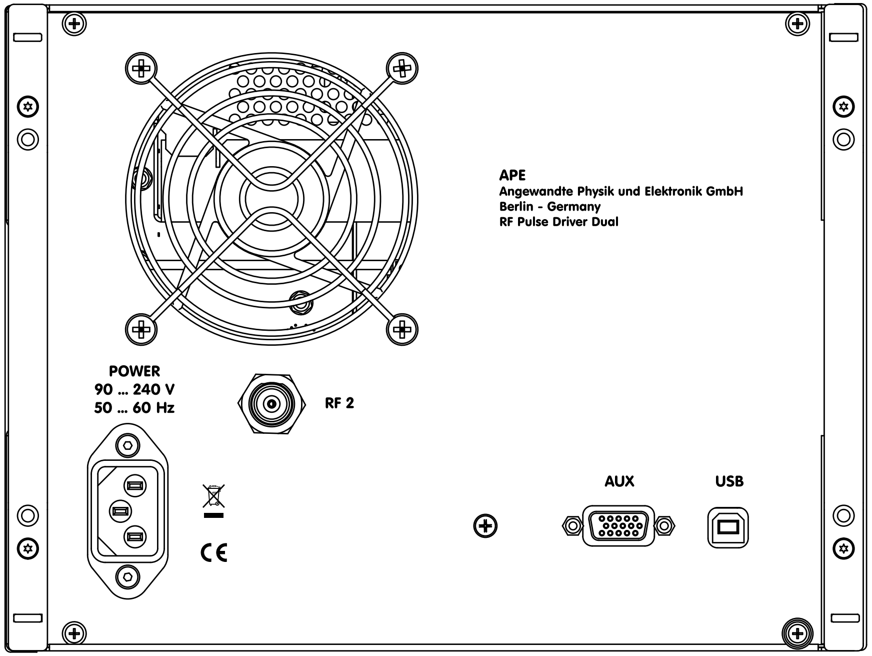


Fig. 5 Driver electronics unit rear panel

4.1 Cable Connection and Start Up

- Connect the RF signal input cables of the optics module with the TNC output “RF” of the driver electronics (RF1 at the front and RF2 at the rear panel). You should only use the delivered RF connection cable without extension to ensure an optimum fitting of the RF components.
- Give the synchronization signal with laser repetition rate (for instance from a fast photo diode) to the „SEED“ BNC input at the front panel of the driver electronics.

- At the “PULSE MONITOR” output pulsed signals (500 mV) synchronously to the selected laser pulses are available. For precise triggering it is recommended to use a 50 Ω termination which causes the voltage level to slightly drop down.
- The “SEED MONITOR” output gives you a monitor signal of the seed input.
- The “EXT. TRIGGER“ input can be used for external triggering up to 3 MHz with a TTL signal. In this case the laser pulse following the trigger signal will be selected. Choose the „EXTERN“ operation mode at the controller in this case (see also paragraph “External triggering” in this manual). If you do not use the external trigger mode please leave the “EXTERN TRIGGER“ input disconnected to avoid disturbances of the RF signal.
- Connect the power cord to the rear panel of the electronics and the wall socket.
- After having connected the signal cables the power can be switched on at the front panel. The „ON” state is indicated by a red LED in the „ON“ button. The display will show you all settings and the measured oscillator repetition rate.
- For stable operation please allow the controller for 15 min warm-up.
- The RF power can be switched on and off at the „RF1 on/off“ and „RF2 on/off” buttons. The „ON“ state is indicated by the green LED in the RF buttons.

CAUTION! Connect or disconnect the RF-signal cables only when the RF power is switched off!

4.2 Function of Buttons

RF1 on|off and RF2 on|off

RF buttons switch on and off the RF power. Green lightning button signalize RF power on. Green blinking or red signalize an error, RF output is disabled. See error messages for details.

Softkey1/2

The keys below the display has variable function (moving cursor or accept messages), depending the menu state.

PHASE knob

Adjust the RF signal phase using the Phase knob.

MENU knob

Menu navigation and parameter adjustment is simply made with the menu knob (see below 4.4).

4.3 Display

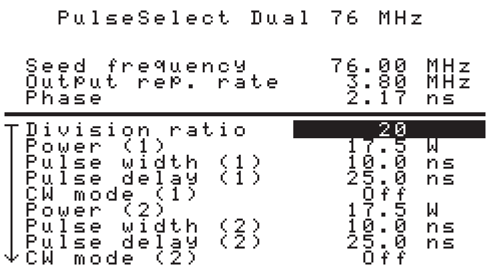


Fig. 6a

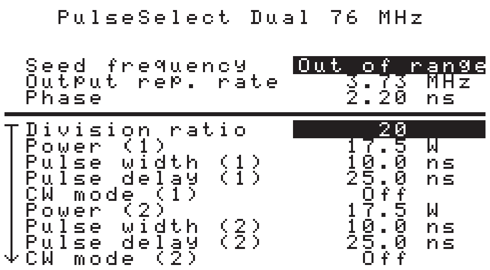


Fig 6b

The Display shows in the upper the name of the unit and the predifined laser repetition rate (as ordered) (Fig. 6a). The seed frequency should be within a range of ± 1 MHz of this value.

- SEED FREQUENCY

The measured seed input frequency is displayed. The frequency is measured every second. When the frequency leaves valid range (± 1 MHz of the predefined repetition rate given in the top line) a blinking message appear (Fig. 6b).

- OUTPUT REPETITION RATE

When internal trigger mode is selected, repetition rate is calculated by deviding the seed frequency by the division ratio. During external trigger mode the frequency of the external trigger input is measured and displayed.

- PHASE

The phase of the RF signal can be controlled by the separate phase knob. The phase shift causes a shift in the range from 0 to 3 ns.

- PARAMETER SETTINGS

In the bottom half the menus for parameter setting are placed.

4.4 Setting the Operational Parameters

The operational parameters are chosen at the controller unit with the two button below the display and the blue rotary knob. To adjust the phase, there is separate the black knob. Parameters will be saved at power off and restored next power on. For safety reasons RF is always off directly after turning on the device.

Menu

By turning the blue menu knob you can navigate via the menus (see Fig. 7). To change a parameter, select the corresponding line and press the blue knob. When you see a blinking cursor square, the corresponding dezimal position of parameter can be changed by turning the menu knob. With the two buttons below the display you can shift the cursor left or right to control more raw or fine. Changes will be set immediately. To leave edit mode press menu knob again.

Main Menu	Division ratio
	Power (1)
	Pulse width (1)
	Pulse delay (1)
	CW mode (1)
	Power (2)
	Pulse width (2)
	Pulse delay (2)
	CW mode (2)
	Trigger mode
	Display
	LCD Backlight
	Default values
	Settings
	Seed trigger lev.
	Beep
	Factory defaults
	Firmware update
Settings Menu	Back

Fig. 7 Menu structure

To enter a submenu (identified by ‚-->‘) also press the menu knob. To move back to the upper menu, select the last line containing ‚Back <--‘ and press menu knob.

MAIN MENU

Division Ratio („DR“)

Division ratio of the internal frequency divider for the laser repetition rate, the synchronization signal of which is connected to the „SEED“ input. It determines the repetition rate of the output signal of the pulse selector shown in the upper part of the display. When set to „20“, for instance, every 20th laser pulse is diffracted to the 1st order, when set to „30“ every 30th pulse is diffracted and so on.

Range: 20 ... 5000
10 ... 5000 optinal
2 ... 260000 optional

Power (1) and Power (2)

Range: 0.5 ... 17.5 W

These are the output RF powers in Watts with 50 Ω load. At division ratios smaler than 1:20 the maximum possible setting is automatically limited to a value to avoid damage of the crystal (also depending on pulse width setting). This is indicated by „!!“ on the display (see Fig. 8). To unmark selection go to power value and press menu knob. The actual limit also depends on the chosen setting of the pulse width.

Adjust these parameters while watching the output laser pulses with a fast photodiode and an oscilloscope and optimise for high diffraction efficiency and high pulse to pulse contrast ratio!


```
    PulseSelect Dual 76 MHz

 Seed frequency        76.00 MHz
 Output rep. rate       4.00 MHz
 Phase                  2.22 ns
 ---------------------------------
 Division ratio           19
 Power (1)          !!  16.2 W
 Pulse width (1)        10.0 ns
 Pulse delay (1)        25.0 ns
 CW mode (1)             Off
 Power (2)          !!  16.2 W
 Pulse width (2)        10.0 ns
 Pulse delay (2)        25.0 ns
 CW mode (2)             Off
```

Fig. 8

Pulse width (1) and Pulse width (2)

Widths of the single RF pulses in ns.

Range: 4.0 ... 15.0 ns
4.0 ... 25.0 ns optional

Adjust these parameters while watching the output laser pulses with a fast photodiode and an oscilloscope and optimize for high diffraction efficiency and high pulse to pulse contrast ratio!

For the 25 ns pulse width option and high repetition rates the pulse width may be reduced automatically to get a minimum „ OFF” time of 7 ns betwen two output pulses. In this case the pulse width is marked by „!!“. To unmark item go to pulse width and press menu knob.

Pulse delay (1) and Pulse delay (2)

Delay of the RF1 and RF2 output pulses relative to the synchronization pulses („SEED“).

Range: 0 ... 50.0 ns

Adjust these parameters while watching the output laser pulses with a fast photodiode and an oscilloscope and optimize for high diffraction efficiency and high pulse to pulse contrast ratio!

CW

Range: on|off

The CW button switcheson and off the cw-mode with a continous RF signal. The RF signal is generated by an internal oscillator without an external seed signal. The RF power in CW mode is about 400 mW.

If cw-mode is on, power, pulse width and delay can not be changed.

Trigger Mode

Range: intern/extern

Synchronization of the RF pulses can be achieved by internal or external trigger signal. Internal trigger signal is generated by the internal frequency divider for the laser repetition rate. The repetition rate is controlled by the division ratio.

When selecting external trigger mode the “EXT. TRIGGER” input must be used for external triggering with a TTL signal (see Fig. 9). In this case the laser pulse following the trigger signal will be selected.


```
      PulseSelect Dual 76 MHz

 Seed frequency        76.00 MHz
 Output rep. rate       1.60 MHz
 Phase                  2.18 ns
 ---------------------------------
 Division ratio       -------
 Power (1)              17.5 W
 Pulse width (1)        10.0 ns
 Pulse delay (1)        25.0 ns
 CW mode (1)             Off
 Power (2)              17.5 W
 Pulse width (2)        10.0 ns
 Pulse delay (2)        25.0 ns
 CW mode (2)             Off
```

Fig. 9

If you do not use the external trigger mode, the “EXTERN TRIGGER“ input should be left open, otherwise the RF pulse quality could be affected.

The maximum repetition rate achievable with external triggering is 3 MHz. If the frequency of the external trigger exceed 3 MHz the message “Limited!!“ appears at the output repetition rate display.

DISPLAY

Range: ON/OFF

The display light can be switched ON/OFF by pressing menu knob.

LCD BACKLIGHT

Range: 10..100%

The Display backlight can be dimmed down to 10% to avoid unintentional light.

DEFAULT VALUES

This Item is used to set the parameters Division ratio, Pulse delay, Pulse Width, Trigger mode and RF Power to default value.

SETTINGS

Switches to the submenu SETTINGS.

<u>SETTING MENU</u>

SEED TRIGGER LEVEL

Range: 00..800 mV

In some cases it can be necessary to adjust the trigger level for the seed input.

BEEP

Range: ON/OFF

When on, a buzzer signalize errors and warnings. Also if you reach the end of parameter range a signal ton is generated.

FACTORY DEFAULTS

When this item is selected the seed trigger level can be reset to the factory calibration value. The value will be reset only when the appearing message was accepted with OK.

FIRMWARE UPDATE

For future use the device firmware can be updated. Only available in agreement with service personnel.

BACK

Leave the Settings menu, go back to main menu. Setting the Operational Parameters.

5. Fine Adjustment of the Optics

The fine adjustment of the optics should also be done at first with attenuated laser beam. After basic alignment (see chapter „Installation and Basic Alignment“ in this manual) and connection of the optics module to the driver electronics the power can be switched on at the electronics.

Start the adjustment with the first modulator stage. First you should optimize for single pass operation, after that adjust the second modulator stage.

Choose CW mode for channel 1 by using the menu of the controller (see Chapter 4). A CW signal with about 300 mW amplitude is given to the modulator crystal.

Now the modulator crystal has to be adjusted so that a diffracted beam in the 1st order is to be seen. Proceed in the following steps:

- Place a beam stop (for instance black aluminium) in front of the collimating mirror CM1 to screen the laser spot. Use an IR viewer to watch the spot if necessary.
- Now adjust the vertical position of the modulator using the vertical position adjustment screw [10] to have the beam at about 1/4 of the modulator height from the transducer. (The transducer is located at the bottom of the modulator crystal.)
- Set the Bragg angle adjustment [9] to the value given in the test protocol.
- While watching the spot on the screen slide the crystal horizontally about 2 mm in each direction from the center position of the beam (use [7]) until a weak second spot appears 4 ... 6 mm above the zero order spot. To make sure that this is the 1st order beam switch off and on the RF signal („RF 1 ON/OFF“ button). Then the spot must disappear and appear.
- Switch on the RF signal again and adjust the horizontal modulator position and the Bragg angle to roughly maximize the 1st order intensity.

- If no diffracted beam can be observed over the whole horizontal adjustment range, slightly change the Bragg angle (use [9])and repeat the above steps. Make also sure that the RF power is switched on (green LED at „RF 1 ON/OFF“) and no fault condition is indicated by the red LED „FAULT“ near the RF output.
- Once you roughly have optimized the diffracted beam by appearance remove the beam stop (screen) from collimating mirror CM1. Adjust the CM1 tilt controls [4, 5] to let the diffracted beam hit the focusing mirror FM2 of the second modulator stage centered. Use the adjustable beam stop BS1 to suppress the zero order beam. Make sure that the diffracted beam does not strike the modulator socket of Mod2. The diffracted beam should now hit the collimating mirror CM2 centered, and after that leave the optics through the brewster window BW3 parallel to the table top. Correct for this using the tilt adjustment screws of focusing mirror FM2 and collimating mirror CM2.
- After having roughly optimized the adjustment, observe the diffracted beam again and correct Bragg angle and horizontal position of the second crystal, if necessary.
- Place a laser power meter behind the beam output at BW3 to measure the power in the diffracted beam. Remove the attenuators from the beam path to ensure maximum beam quality. To further maximize the diffraction efficiency of stage 1, adjust the horizontal and vertical position of modulator Mod1, as well as the Bragg and Brewster angles of the modulator crystal. The vertical position should be adjusted so that the beam passes the crystal as close as possible to the transducer at the bottom of the crystal.

After having maximized the power of the diffracted beam in cw mode the first stage of the PulseSelect Dual must be optimized for pulsed operation.

- To do this allow the zero order beam to pass the beam stop BS1, modulator stage 2, and the output brewster window BW3, i.e. go down

with BS1 and use CN1 vertical tild control to center the zero order beam on mirror FM2. Readjust FM2 and CM2 so that the zero order beam leave the optics through the brewster window BW3 parallel to the table top. Detect the pulses of this beam with a fast photodiode behind the beam output and an oscilloscope. Use an additional aperture to block the diffracted 1st order beam if necessary. Trigger the oscilloscope with the „PULSE MONITOR“ output signal of the PulseSelect.

- Switch off the RF output signal at the „RF 1 ON/OFF“ button and change the setting in the channel 1 power menu from „CW“ to PO = 16.5 W. Set the following parameters for channel 1: DR = 20, PW = 8.0 ns, DE = 1.0 ns. Switch RF on again. Now every 20th pulse should appear with smaller amplitude on the oscilloscope. The ratio between diffracted and non-diffracted pulses is a measure of the diffraction efficiency.
- Maximize the diffraction efficiency by variation of Pulse width (PW), RF-Power (PO), and Delay (DE).
- Maximize the diffraction efficiency by changing the Bragg and Brewster angles of the crystal again [8, 9]. Change the Brewster angle in small steps always correcting the horizontal position.
- The diffraction efficiency and contrast ratio can now be further optimized by adjusting the horizontal position of the modulator focusing screw ([1] in Fig. 2). Change the position in small steps while always correcting the modulator horizontal and vertical position [7 and 10].
- By directing the diffracted beam to the photodiode (use the tilt controls of collimating mirror CM2) you can check the contrast ratio between diffracted and non-diffracted pulses.

After having found the optimum adjustment and operational parameters adjust the position and collimation of the diffracted beam again with the collimating mirror CM1 controls [4, 5, 6]. Use the adjustable beam stop BS1 to block the zero order beam.

Adjustment of modulator stage 2:

- Change to CW operation mode for stage 1 again. Leave all other settings and alignments for channel 1 unchanged!
- Follow the steps described above for the adjustment of stage 1 respectively to adjust stage 2. Use the diffracted first order beam of stage 1 (operated in CW mode) as input beam for stage 2. Start with CW optimization and after that change to pulsed operation of channel 2.

After having optimized the operation of the two single stages you can go to dual operation mode. Switch the RF output signals off for both channels and set all parameters to the optimum values for pulsed operation you have determined before. Switch RF outputs on again. Probably you will see a diffracted beam from stage 1 reaching modulator 2, but no diffracted beam from modulator 2. This is because both modulators must still be synchronized to select the same pulse relative to the trigger available at „PULSE MONITOR“. Slowly adjust the vertical position of Mod2 using the adjustment screw [10] until you see a diffracted beam in the first order behind the modulator. Monitor these pulses with the fast photodiode and the oscilloscope and optimize them with respect to intensity and contrast ratio by adjusting the vertical position of modulator 2. Make sure again that the beam stop BS1 blocks the zero order beam of the first stage and the beam stop BS2 blocks the zero order beam of the second stage.

Now the PulseSelect is adjusted. Set the Division Ratio (DR) to the desired value and start your experiment.

Once the optimum adjustment is found only slight corrections are necessary when the system is turned on next time. If you change the laser wavelength, the Bragg angle [9] needs readjustment.

6. Error Signal „FAULT“

The electronics of the PulseSwitch has an integrated safety circuit that prevents the system from putting out high RF power levels that could damage the modulator crystal. A „FAULT“ message on the screen indicates a cw output power level exceeding 0.8 W. In this case the RF output will be switched off automatically and the LED turns to the colour red at the top.

Possible reasons for this fault can be, for instance, unstable triggering conditions at the „SEED“ input or loose cable connections at RF OUT to the optics and following back reflections and defective electronics.

In the case the „FAULT“ lights up during operation, check the system for possible error sources (for instance external triggering with high frequency, unstable seed input signal, loose cable connections) and eliminate them, switch on the RF. Confirm the „FAULT“ message on the display. Then it is possible to switch on the PR power signal again. If still no normal operation is possible („FAULT“ is signalled again after switching on RF output) or the error occurs repeatedly during operation with the internal frequency divider, please contact the service personnel of your supplier for technical support.

7. Single Stage Operation

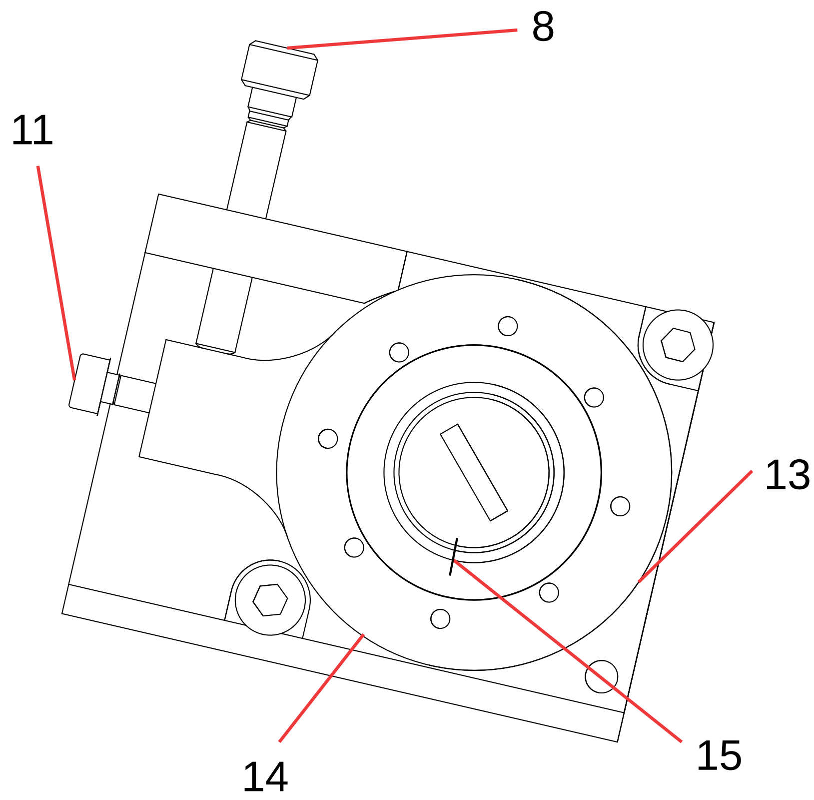
For single stage operation remove focusing mirror FM2 from its holder and let the diffracted beam leave the optics at brewster window BW2. For adjustment follow the steps described in the articles above.

Appendix 1: Installation of the Bragg Cell

Caution! Do not touch the modulator crystal! The modulator is very sensitive against all kinds of pollution, scratching, and mechanical shock.

Set the Brewster angle adjustment screw [8] to a middle position. Unlock the lock screw for the rough Brewster angle adjustment [11] with a hex key and rotate the modulator holder to 0 degree. Lock the screw [11].

There are two small screws accessible through two holes in the side of the modulator holder with a 0.9 mm hex Allen key [13,14]. These two screws hold the modulator socket. Loosen the screws so far that the modulator socket fits into the 1 inch hole of the modulator holder. Remove the modulator again. Thread the modulator RF cable from the bottom side through the 1 inch hole of the modulator holder. Screw the SMA connector of the cable tightly to the SMA connector of the modulator socket by hand. Do not use a tool! Try to leave the cable stress-free when holding the modulator in its later direction. The correct direction is given by the line mark at the modulator socket (see Fig. 10). This line must be right-angled to the beam direction. This is given when the line points to the hole near the 140° mark. Set the modulator into the holder and fix it with the two screws [13, 14].



8	-	Brewster angle control
11	-	Rough Brewster angle adjustment lock screw
13, 14	-	Modulator lock screws, access holes
15	-	Mark for modulator direction

Fig. 10 Modulator assembly