GWU
versaScan

Beta - Barium Borate

Optical Parametric Oscillator

User Manual

V 1.63

1 Laser safety

DANGER
Visible AND Invisible Laser Radiation

Emission of visible (signal wave: 398 nm – 709 nm) and invisible (idler wave: 710 nm – 3300 nm) laser radiation as well as pump laser light at 355 nm.

Exposure to direct or reflected beams can cause severe eye and skin damage.

Wavelength conversion pumped by **class 4 laser** product.

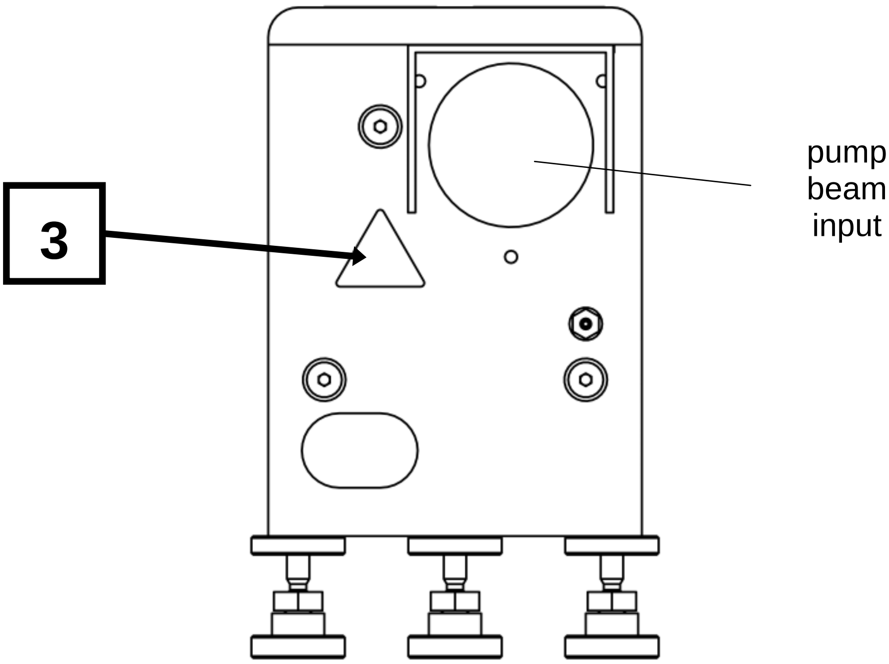
- Avoid looking at the output beam and reflections
- Always use protective eyewear
- Operate the versaScan at the lowest possible beam intensity allowed by the requirements of the application
- Maintain high ambient light level
- Avoid unnecessary reflections: Use enclosures for beam paths and shields
- Let the beam propagate only in a restricted area in a horizontal plane which is not at the typical height of the eyes
- Do not move your head (eyes) down to the height of the beam path
- The laser safety beam shield (fig. 5 (3)) and the laser safety beam tube (fig. 5 (5)) have to be fixed in place any time the pump laser light is entering the versaScan! Otherwise harmful reflections from the tilted BBO crystal will put the user at high risk!

1.1 Location of the safety labels

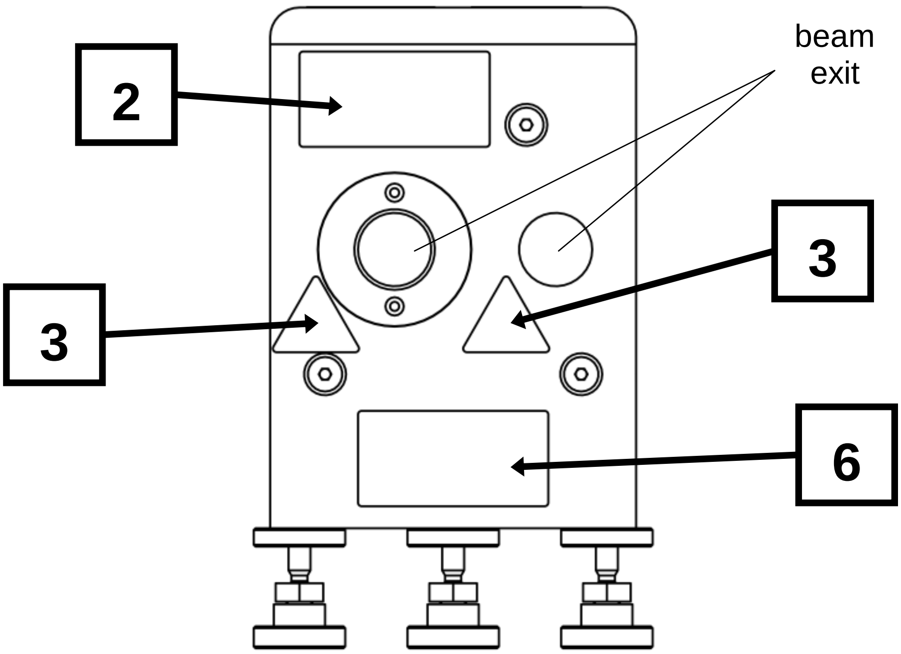
The following safety labels are used throughout the versaScan. Refer to diagrams A & B for their location. The labels must not be removed or defaced. Immediately replace any missing labels.

Label types are shown in 1.1.1 and 1.1.2.

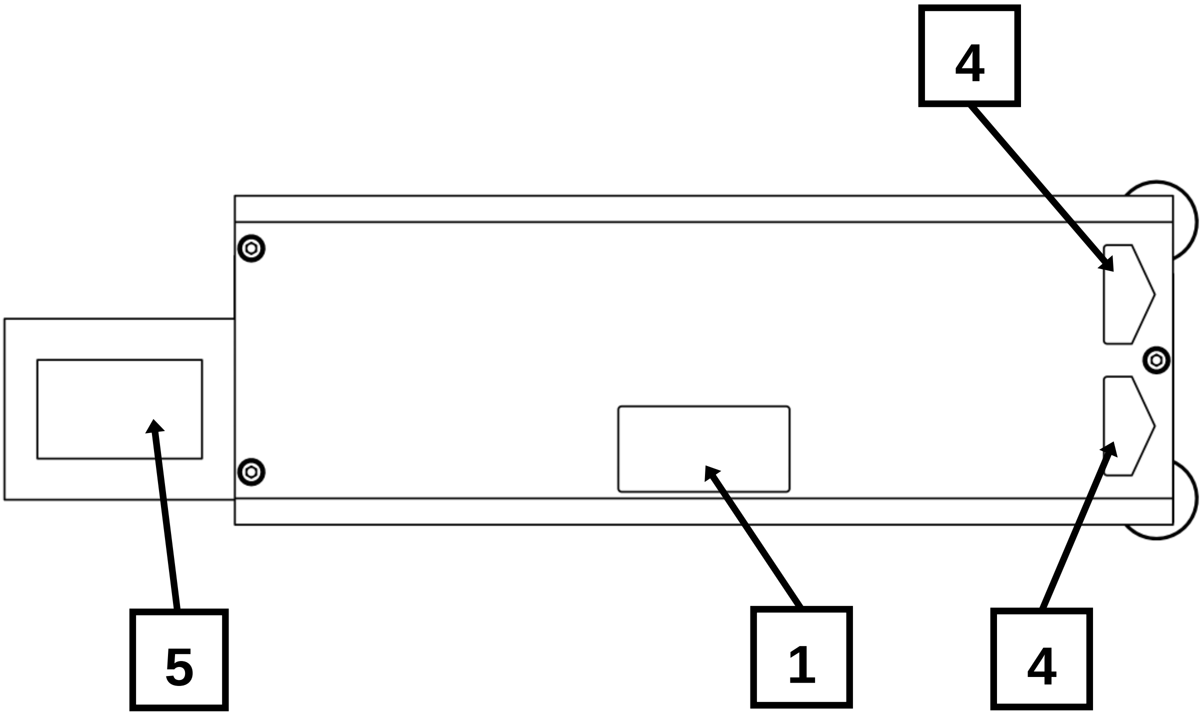
The laser safety officer must add/replace the safety labels with labels in the language typical for the country corresponding to the regional laser safety regulations.



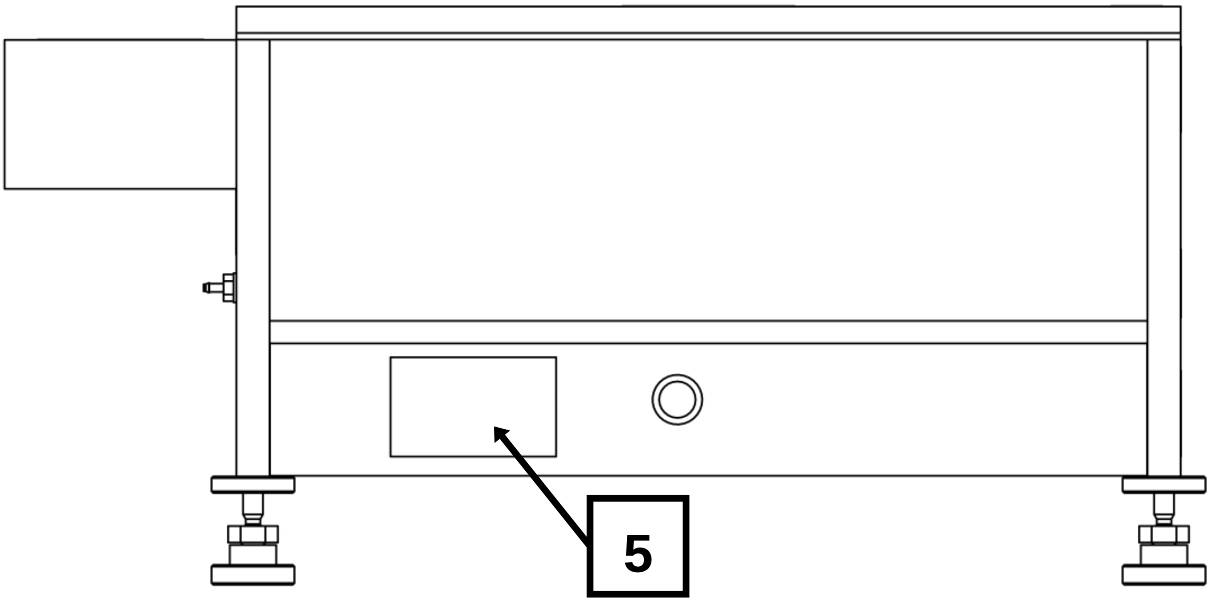
Input & output panels of the versaScan



Label location diagram A.



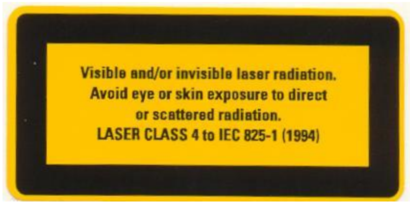
Top & front panels of the versaScan



Label location diagram B.

1.1.1 Label types – English

Label 1
Part no. 902108



Label 2
Part no. 902104

Label 3
Part no. 902100

Label 4
Part no. 902102

Label 5
Part no. 902101

Label 6
Part no. 902105

1.1.2 Label types – German

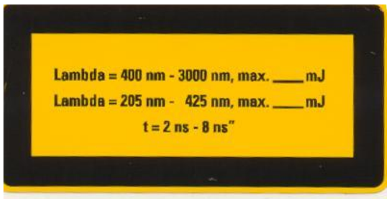
Label 1
Part no. 902107

Label 2
Part no. 902103

Label 3
Part no. 902100

Label 4
Part no. 902102

Label 5
Part no. 902101



Label 6
Part no. 902105

2 Pump laser requirements

wavelength	355 nm
pulse duration	5 ns – 9 ns (shorter pulse length on request)
repetition rate	up to 30 Hz (higher repetition rates on request)
spatial beam profile	homogenous beam profile (without hot spots)
spectral width	< 1 cm^{-1}
pump beam divergence (at 355 nm)	versaScan/BB: < 0.5 mrad (full angle) versaScan/MB: < 0.8 mrad (full angle) possible is up to 1.5 mrad for /BB and up to 3 mrad for /MB with reduced output and energy stability
polarization	horizontal

3 Specifications of the versaScan

dimensions	L x W: 285 x 100 mm² H: 142 mm + feet. Standard feet = 35 nm ± 10 mm Feet elongations 40 mm , 55 mm and 82 mm available
non-linear crystal	β - BaB_2O_4 (BBO)
phase matching	versaScan/BB and versaScan/BB/HE: Type I versaScan/MB: Type II
pump energy density	< 0.65 J/cm² (recommended: 0.5 J/cm² – 0.6 J/cm², adjustable by the use of appropriate telescope lenses)
tuning range	signal wave: 410 nm – 709 nm idler wave: 710 nm – 2630 nm
threshold fluence	< 0.2 J/cm²
total efficiency (signal + idler)	typically > 20% at 435 nm – 2000 nm (for pump energies > 80 mJ/pulse @ 355 nm)
pulse duration	1 ns - 2 ns shorter than pump pulse duration
energy ratio signal / idler	see figure 1
typical spectral width	depending on pump pulse length versaScan/BB (for versaScan/BB/HE add + 10%): See figures 3 and 4 versaScan/MB: 4 cm^{-1} for 7 ns pump pulse length 7 cm^{-1} for 4 ns pump pulse length
typical divergence	depending on pump pulse length versaScan/BB signal wave: 2.5 mrad – 8 mrad (divergent) idler wave: 3.5 mrad – 10 mrad, focussing (convergent) versaScan/MB: horizontal: < 0.7 mrad (signal and idler waves) vertical: signal: 3 mrad – 9 mrad (divergent) idler: 4 mrad – 11 mrad, focussing (convergent)
polarization	vertical, exception: The idler wave of versaScan/MB is horizontal

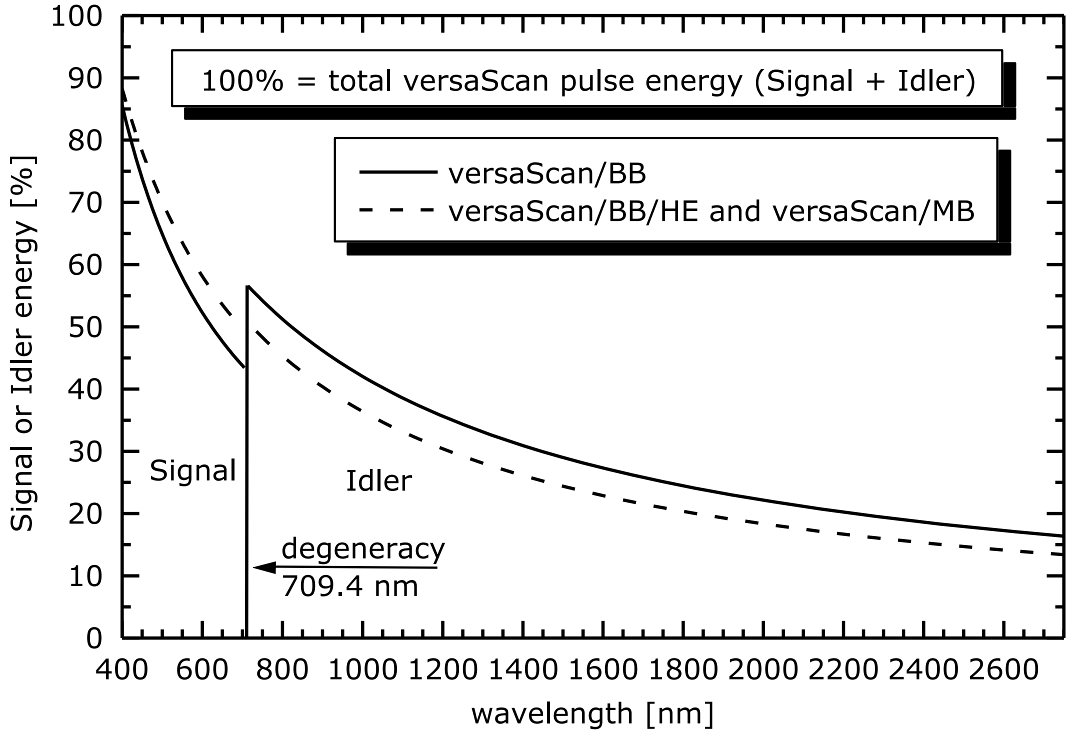


Figure 1: Distribution of the versaScan pulse energy between Signal and Idler

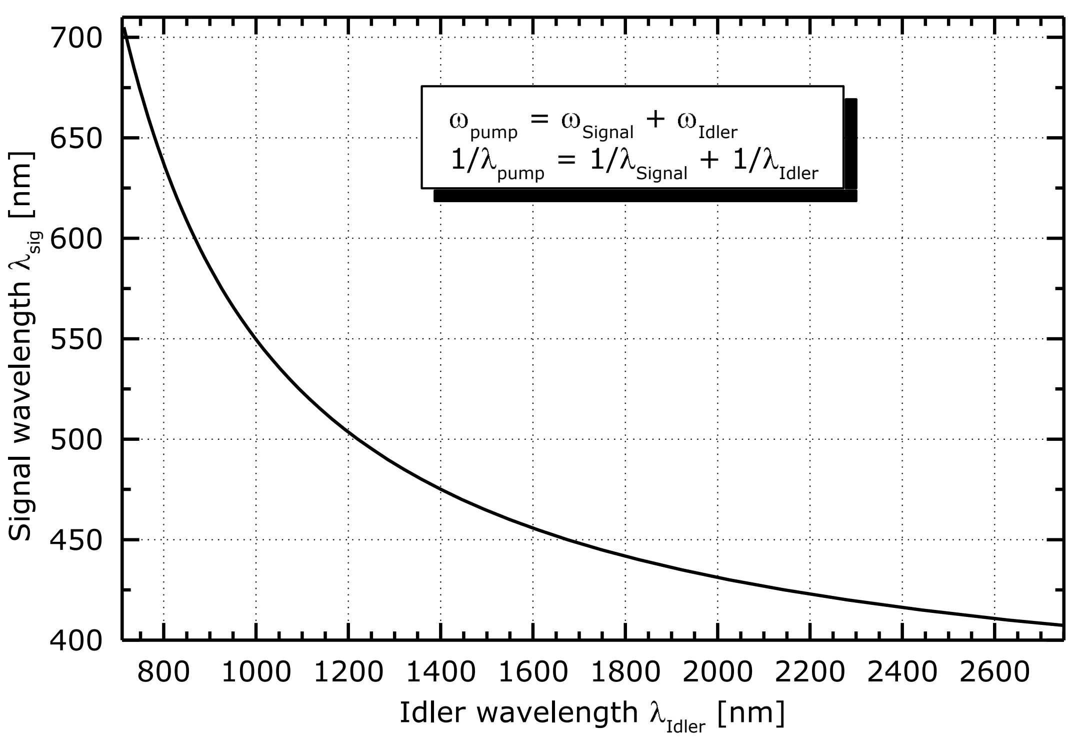


Figure 2: Relation between Signal and Idler wavelengths

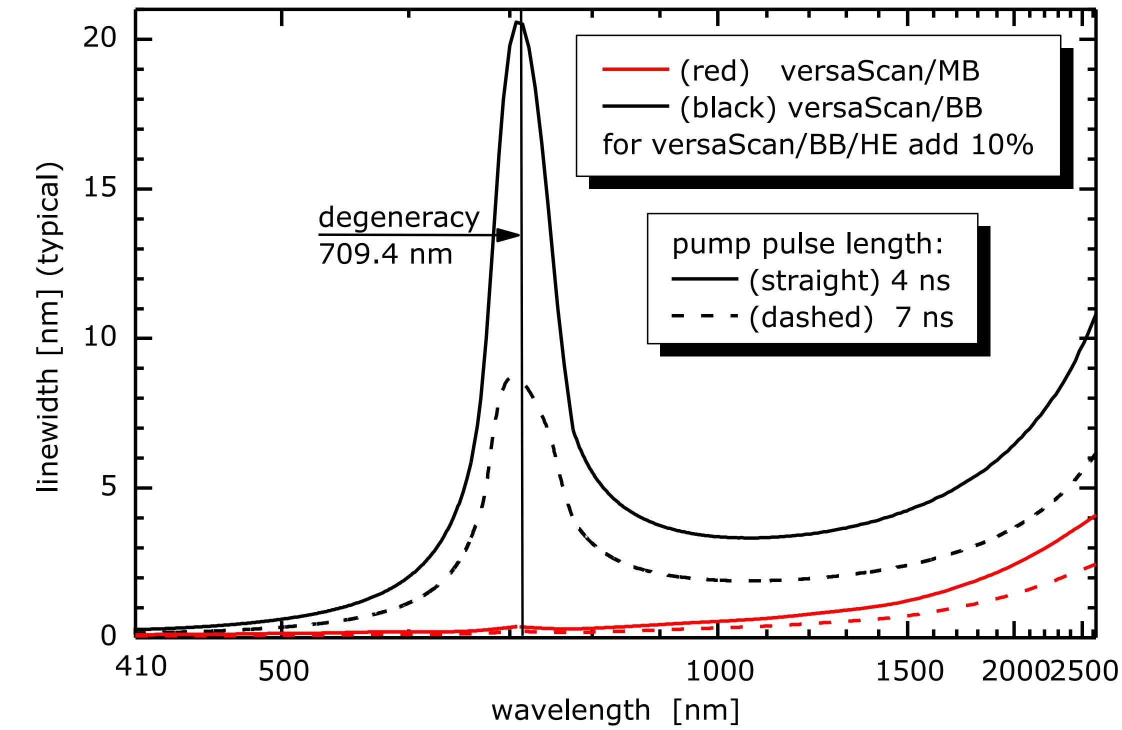


Figure 3: Typical spectral width of the versaScan

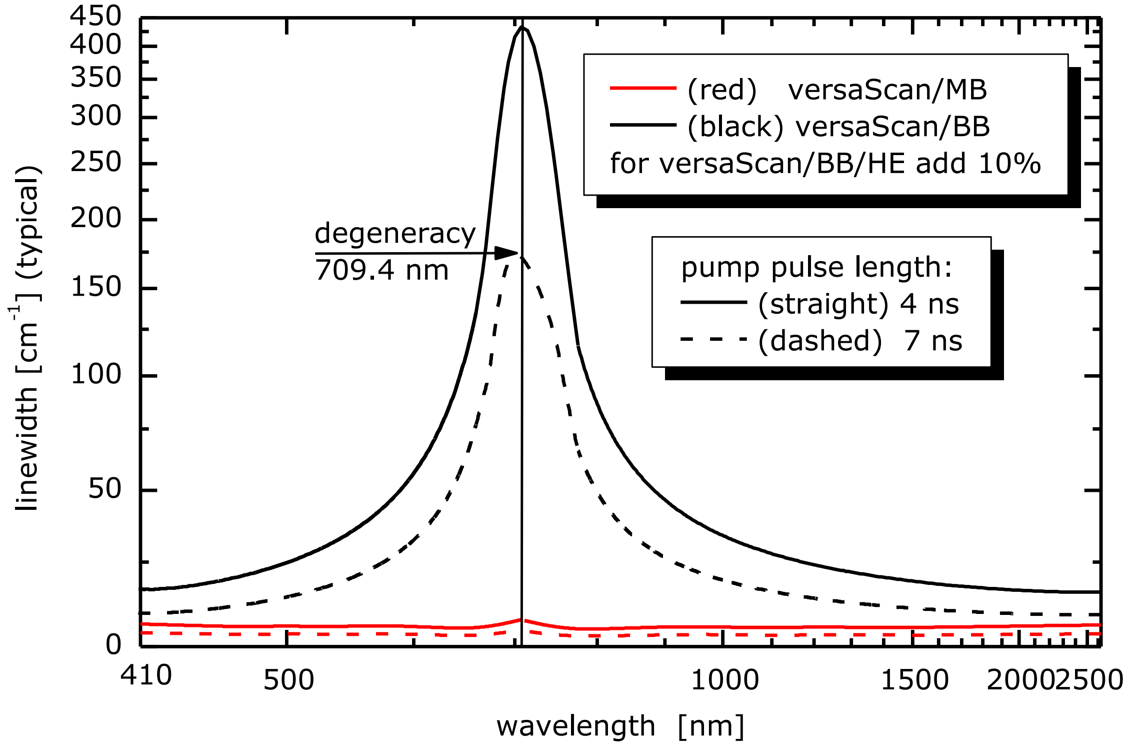


Figure 4: Typical spectral width of the versaScan

3.1 Electromagnetic compatibility (EMC) of the option M

The GWU OPOs emit very low electromagnetic radio frequency radiation in case of the option M (motorised wavelength tuning).
This statement did not take into account possible emissions by the pump laser.
The GWU OPOs have been undergoing a comprehensive testing of the EMC according to the FCC regulations that apply in the USA.
Important: In order to maintain the low EMC emissions of the GWU OPOs, it is necessary to use only the original connection cables supplied by GWU. Follow the instructions in the chapter “Option M”.

NOTE: This equipment has been tested and found to comply with the limits for Class A digital device pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with this user manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

4 Important precautions

The versaScan should only be operated with all its covers closed and fixed.
Laser safety: When opening the cover (e.g. for alignment) ensure that the laser safety beam shield (fig. 5 (3)) and the laser safety beam tube (fig. 5 (5)) is in place any time pump laser light is entering the versaScan! Otherwise harmful reflections from the tilted BBO crystal will put the user at high risk!

Avoid any optical or mechanical damage of the optical components.

Do not touch the optical components! Wear gloves or use weak plastic tweezers to hold optical components!

Ensure that the surfaces of the optics are free from dust. Particles burned onto the dielectric coatings of the mirrors or the crystal surfaces can lead to reduced output energies.
Dust particles and pollutants should be removed by blowing clean air onto the surfaces. Never blow your (wet!) breath onto the optics!

Never use acetone to clean the BBO crystals!

If the versaScan will not be in use for a long period of time we recommend to store the BBO crystal in a clean and dry place.
For transport and delivery the BBO is packed in a small plastic transparent transportation container which protects the crystal from mechanical shock. Do not use this transportation container to store the crystal. It is appropriate only for the short storage of during the transport. After the delivery take out the crystal and place the crystal in a clean and dry place. Preferably use a desiccator for storage.

Avoid focussed back reflection of the OPO output into the OPO! It could possibly damage optical components.

The alignment of the telescope of the versaScan should only be done by authorized service engineers. They have to be extremely careful that the pump beam exits the telescope with minimum divergence and does not exhibit a focus. There is no need to readjust the telescope after initial installation unless the pump laser beam parameters has been changed.

The versaScan resonator should not be exposed to pump energy densities of more than 0.65 J/cm^2 for a pump pulse duration > 4 ns and 0.6 J/cm^2 for a pump pulse duration between 2.5 ns and 4 ns.

5 Schematic set up of the versaScan

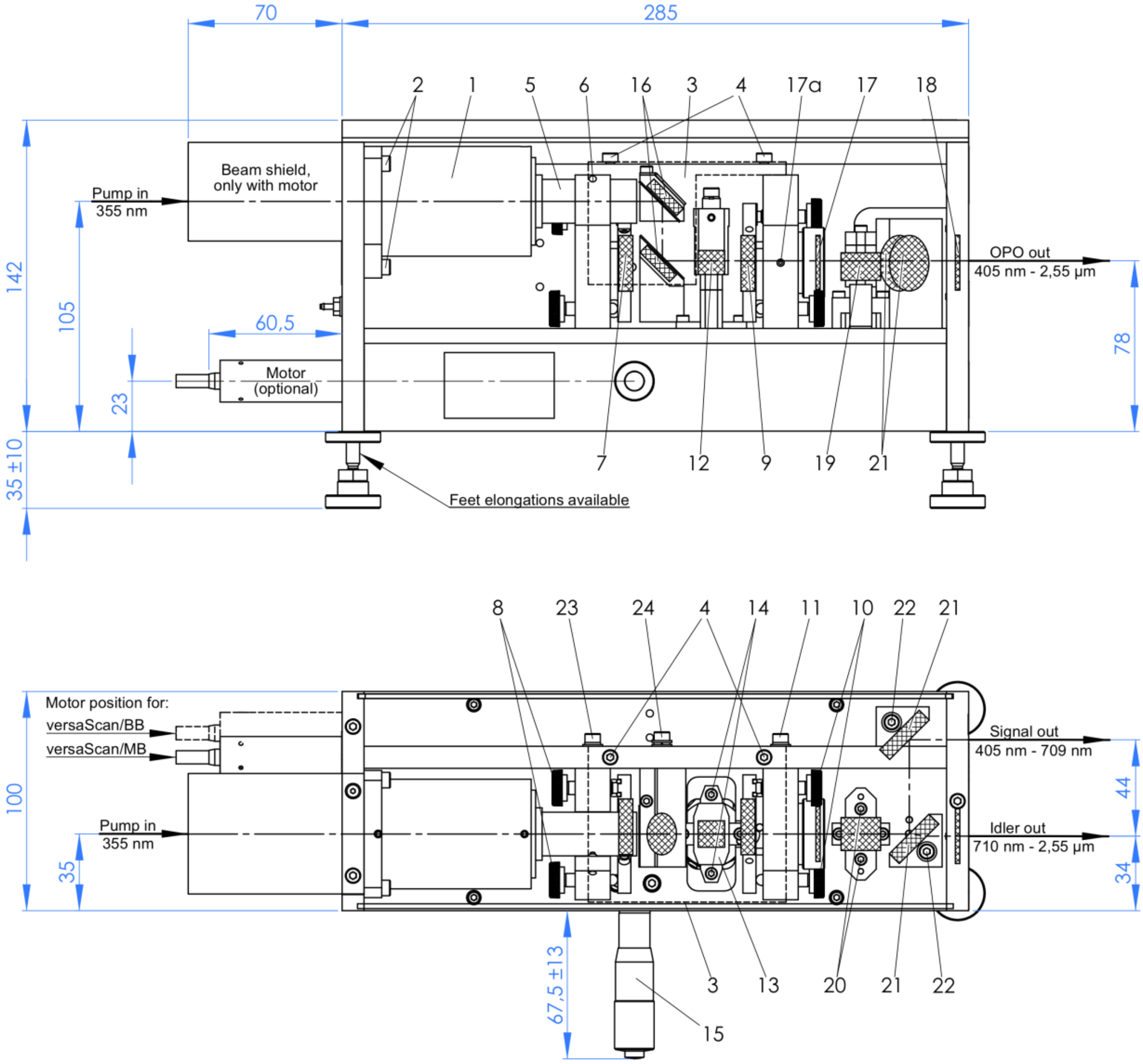


Figure 5: Schematic set up of the versaScan

1 Telescope assembly
2 Screws to the fix telescope
3 Laser safety beam shield (dashed)
4 Screws to fix laser safety beam shield
5 Laser safety beam tube
6 Screw to fix the laser safety beam tube
7 Resonator end mirror
8 End mirror alignment screws
9 Output coupler
10 Output coupler alignment screws
11 Screw to fix the output coupler holder
12 BBO crystal
13 Crystal rotation stage
14 Screws to fix the crystal holder
15 Wavelength controlling micrometer
16 Pump mirrors (refer to chapter 6.4)
17 UV-filter 17a Set screw UV-filter
18 VIS-filter
19 Compensator
20 Screws to fix the compensator holder
21 Dichroic signal/idler separators
22 Screw to fix the signal/idler separator
23 Screw to fix the end mirror holder
24 Screws to fix the periscope

6 Installation

6.1 Install the laser back reflection protection (LBP)

In case of a versaScan/BB skip chapter 6.1 and proceed with chapter 6.2. The laser back reflection protection (LBP) is not needed for the versaScan/BB. It is necessary for the versaScan**/BB/HE** and the versaScan**/MB** which are reflecting back some part of the 355 nm pump beam light.

The LBP has to be installed inside the pump laser between the SHG and the THG stage. If there is no place between the SHG and the THG stage inside the pump laser it is possible to install the LBP in front of the SHG stage (where the fundamental 1064 nm radiation of the laser enters the SHG stage).

For a versaScan/BB/HE and for a versaScan/MB build up the OPO in some distance to the pump laser. Choose the distance between the pump laser and the versaScan in a way that the reflection from the versaScan output coupler (figure 5 (9)) does not overlap with the laser pulse at the THG crystal of the pump laser. The light propagates 30 cm each 1 ns. Thus for 5 ns pump pulse length for example the geometrical spread of the pump pulse is 5 x 30 cm = 150 cm and hence the distance between the THG crystal and the OPO resonator should be 150 cm / 2 = 75 cm. In general the distance between the laser THG crystal inside the laser housing and the versaScan output coupler (figure 5 (9)) should be:

Pulse length of the pump laser in [ns] x 15 cm

This is usually fulfilled for a typical distance between the pump laser housing and the versaScan housing of about 30 cm - 40 cm.

6.1.1 LBP: AR coated UV filter

For pump laser output power of up to 3.6 W at 355 nm (e.g. 360 mJ at 10 Hz = 3.6 W) the LBP is consisting of an AR coated UV filter (AR 1064 nm + 532 nm). Just place the UV filter inside the pump laser housing into the laser beam and make sure that it is tilted against the pump laser beam a little bit (3° to 10° DEG) that its back reflection does not enter the YAG rod. As well let the UV filter have a tight contact to some metal parts (e.g. hold it in a metal ring) for cooling purpose. Otherwise the heated up filter may break.

After installing the UV filter check the pump laser output for any evidence of prelasing[1]. Prelasing could damage optics! If prelasing occurs, tilt the UV filter a little more against the laser beam.

6.1.2 LBP: Mirror + beam dump

For pump laser output power of more than 3.6 W at 355 nm (e.g. 200 mJ at 20 Hz = 4 W) the LBP is consisting of a mirror and a beam dump. Place the mirror which

[1] Prelasing means that there is laser light (1064 nm) leaking out of the pump laser BEFORE the Q-switch opens. You have to detect if there is 1064 nm radiation emitted before the main laser pulse e.g. using a (slow) photodiode and an oscilloscope (30 MHz).
Alternatively the Q-switch trigger can be set to external triggering and no trigger signal applied. Then it is not allowed that 1064 nm radiation is emitted by the laser (detected by a sensitive IR detector card).

reflects the 355 nm radiation and transmits 1064 nm and 532 nm radiation under 45° DEG against the laser beam that the back reflection from the OPO is reflected at this mirror (under 90°) into the beam dump.
After installing the mirror and the beam dump, check if the laser beam passes through the (SHG and) THG crystal of the pump laser without clipping. If the laser beam is clipped position the (SHG and) THG stage in a way that the laser beam passes through without clipping. Adjust SHG and THG angle for maximum 355 nm output power of the pump laser.

6.2 Characterize the pump beam

Before installing the versaScan the pump beam characteristic has to be checked.

- Check the pump laser output for any evidence of prelasing[2]. Prelasing can damage optics!
- Check the polarization of the pump laser at 355 nm. It needs to be horizontal.
- Allow the pump laser about half an hour to warm up at full power.
- Optimize the pump laser output at 355 nm:
  Fine adjust the SHG and THG crystal angles.
  If present align the polarization rotator (λ/2-waveplate) in front of these HG stages for max. 355 nm output as well.
  If possible check if the Q-switch delay (parameter of the pump laser control electronic) is optimized for max. laser output.
- Once it is optimized measure the maximum possible output energy of the pump laser at 355 nm ($\mathbf{E_{355}}$).
- Take burn patterns[3] in different distances behind the laser. Inspect the burn patterns for any evidence of hot spots inside the pump beam. Hot spots could damage the OPO optics. The pump beam does not need to be round (even though this is mostly preferred) but the intense part of the beam should form one continuous closed area. The bigger this area is the better. A flat top beam profile is mostly preferred for pumping the GWU OPOs.
- Determine the beam diameter and divergence of the pump beam using the burn patterns. Useful are magnifying glasses and/or a calliper rule. The beam divergence of the pump beam should be less then 0.5 mrad. This means the beam diameter should rise less then 0.5 mm for every 1 m the beam propagates.

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[2] Prelasing means that there is laser light (1064 nm) leaking out of the pump laser BEFORE the Q-switch opens. You have to detect if there is 1064 nm radiation emitted before the main laser pulse e.g. using a (slow) photodiode and an oscilloscope (30 MHz).
Alternatively the Q-switch trigger can be set to external triggering and no trigger signal applied. Then it is not allowed that 1064 nm radiation is emitted by the laser (detected by a sensitive IR detector card).

[3] Use black (exposed and processed) photo paper. Put the photo paper always inside a transparent plastic bag to avoid contamination of the optics with ablated dust powder. The plastic bags have to be free of any imprints on it (e.g. NO recycling sign imprinted). The laser ablation of the imprints will damage optics!
Direct the laser beam onto the photo paper (only one shot at one place). **DANGER:** Be very careful with the reflection of the laser beam from the photo paper. Protect your eyes. Do not look at the photo paper when taking burn pattern!

- Calculate the energy density of the pump beam:
  Pump energy density [mJ/cm²] = E_{355} [mJ] / $r_{horiz.}$ [cm] / $r_{vert.}$ [cm] / π
  with:
    E_{355}: Max. output energy of the pump laser at 355 nm in [mJ/pulse]
    $r_{horiz.}$, $r_{vert.}$: Radius (horizontal / vertical) of the 355 nm radiation in [cm]
    π: 3.14

  If the intense part of the pump beam does not fill the whole beam then calculate the energy density with a marked down beam radius (between the radius of the whole beam and the radius of the intense part).
  The versaScan shall be pumped at 355 nm with the
  recommended pump energy density = 500 mJ/cm² ... 600 mJ/cm².
  If the energy density of the 355 nm pump beam is different, the energy density has to be changed by using an appropriate set of telescope lenses inside the versaScan telescope assembly. The allowed range is between:
  Allowed pump energy density = 450 mJ/cm² ... 650 mJ/cm²

6.3 Setup of the telescope

The telescope is a Galilean type consisting of a plano-convex and plano-concave lens (see fig. 6 below). Ask your GWU OPO service support for the correct telescope lenses appropriate to your pump laser.
Only authorized service engineers should do the versaScan telescope setup and alignment. They have to be extremely careful that the pump beam exits the telescope with minimum divergence and does not exhibit a focus and they have to double-check that the correct pump energy density for the versaScan is obtained.
The **pump energy density must not exceed 0.65 J/cm²** but should be higher than 0.45 J/cm² to obtain high conversion efficiency.
To perform the telescope alignment most optics has to be removed from the versaScan.

6.3.1 Possible lens combinations

If the energy density of the pump beam is different the required energy density for the versaScan could be obtained by using one of the lens combinations in the following table 1 and table 2 (see as well Appendix A for non standard lens combinations and for systems built prior to 2011).

Choose an appropriate set of telescope lenses in order to attain within the
target pump energy density = 500 mJ/cm² ... 550 mJ/cm².
At least try to stay within the
recommended pump energy density = 500 mJ/cm² ... 600 mJ/cm².
Never exceed the
allowed pump energy density = 450 mJ/cm² ... 650 mJ/cm².

Table 1: Magnification of the pump beam diameter = lowering the energy density

Diameter magnification	Energy density lowered down to (factor)	Focal length [mm]		Lens distance [mm]	Typical for Quanta-Ray lasers, if OPO crystal height is [mm]
		f_1	f_2		
1 : 1	1.0	No	No	N/A	PRO 230-10, ≥ 10 mm LAB 190-10, 9 mm LAB 170-10, ≥ 8.5 mm
1 : 1.1	0.827	-200	220	20	PRO 230-10, ≥ 10 mm
1 : 1.175	0.724	-200	235	35	PRO 250-10, 11 mm
1 : 1.25	0.64	-200	250	50	PRO 250-10, PRO 270-10, ≥ 11 mm
1 : 1.26	0.633	-175	220	45	PRO 250-10, PRO 270-10, ≥ 11 mm
1 : 1.34	0.555	-175	235	60	PRO 270-10, PRO 290-10, 12.5 mm
1 : 1.43	0.49	-175	250	75	PRO 290-10, 12.5 mm
1 : 1.47	0.465	-150	220	70	
1 : 1.57	0.407	-150	235	85	
1 : 1.67	0.36	-150	250	100	

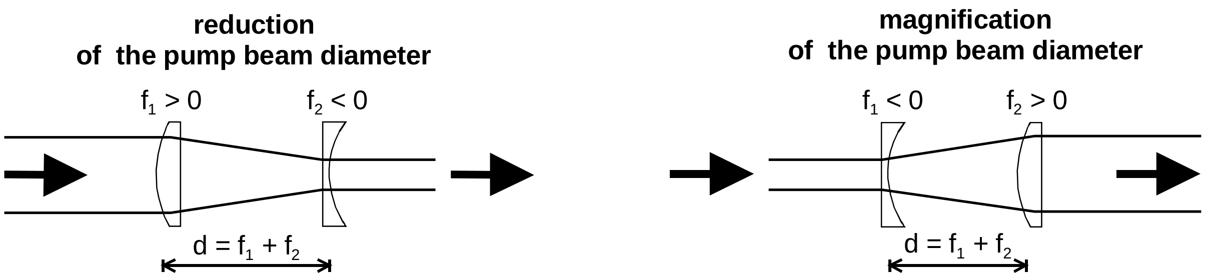
Table 2: Reduction of the pump beam diameter = rising the energy density

Diameter reduction	Energy density rises by (factor)	Focal length [mm]		Lens distance [mm]	Typical for Quanta-Ray lasers, if OPO crystal height is [mm]
		f_1	f_2		
1 : 0.909	1.21	220	-200	20	LAB 170-10, LAB 190-10, ≥ 8 mm
1 : 0.851	1.38	235	-200	35	Standard, LAB 150-10, ≥ 7 mm
1 : 0.80	1.56	250	-200	50	
1 : 0.795	1.58	220	-175	45	
1 : 0.745	1.80	235	-175	60	LAB 130-10, INDI 40-10, 6 mm
1 : 0.7	2.04	250	-175	75	LAB 130-10, INDI 40-10, 5 mm or 6 mm
1 : 0.682	2.15	220	-150	70	LAB 130-10, INDI 40-10, 5 mm
1 : 0.638	2.45	235	-150	85	LAB 130-10, 5 mm
1 : 0.6	2.78	250	-150	100	

Take into account that the beam diameter has to be smaller than the aperture of the OPO crystal as well. It is possible that you have to reduce and limit the pump power of the laser to be able to stay below 600 mJ/cm² in the energy density and to be smaller with the beam diameter then the OPO crystal.

6.3.2 Installation of the lenses

- Take off the laser safety beam tube (fig. 5 (5) & fig. 6 (3)) by loosening the screw fig 5 (6)..
- Loosen the setscrew (fig.6 (8)) and slide out the inner tube (fig. 6 (2)) completely.
- Fix the lenses in the telescope housing with the curved side of the lenses orientated as shown in fig. 6.
  Danger: Take care that the telescope lens is orientated correctly like shown in figure 6! Wrong orientation of the lens curvature can lead to optics damage! The back reflection from the curved side should not exhibit a focus!
- Slide in the inner tube again. Be aware that there are two possibilities, depending on which end you slide in first, resulting in a large change of lens distance.
- Install the laser safety beam tube (fig. 5 (5)).
  Danger: Avoid focussing! Choose a small lens distance before injecting laser light into the telescope for the first time! Focussing occurs if the chosen lens distance is too big.



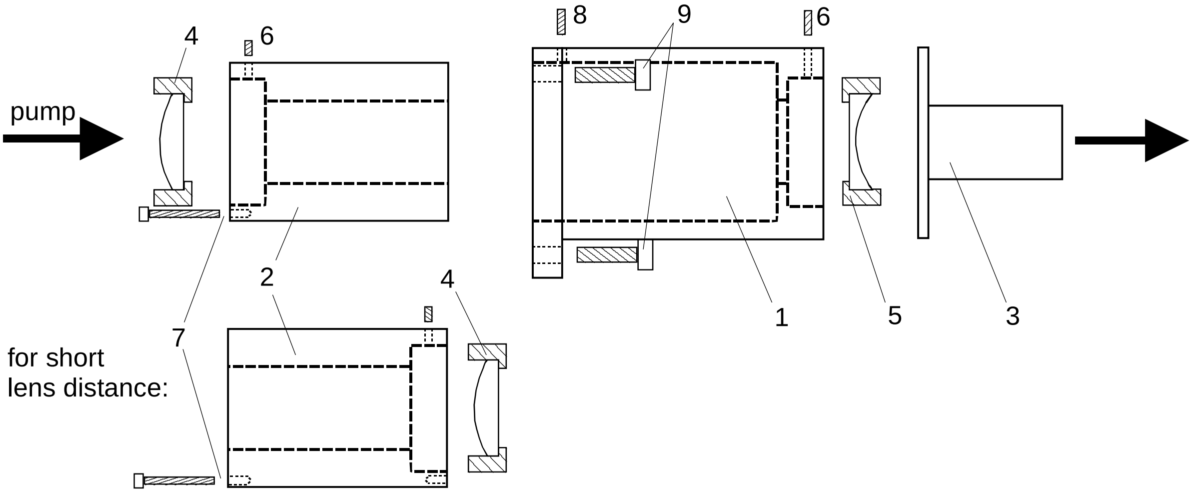


Figure 6: Set up of the telescope:

1 Telescope housing
2 Telescope housing inner tube
3 laser safety beam tube
4 1st lens
5 2nd lens
6 Setscrew for lens holder
7 Use a long screw (M3) to access/slide the inner tube (2)
8 Setscrew for lens distance
9 Setscrew for telescope housing

6.3.3 Adjustment of the lens distance

The telescope lens distance has to be aligned for minimum divergence of the pump beam behind the telescope.

Note: It is not allowed to change the lens distance in order to tweak for the desired beam diameter inside the OPO. If the desired beam diameter and thus the required energy density is not obtained by the present telescope lens combination call your GWU service for an exchange set.

- First take out of the versaScan all optics in the beam path behind the pump mirrors in the periscope (fig. 5 (16)). These are:
  - The BBO crystal holder (fig. 5 (14)), if the BBO crystal (fig. 5 (12)) is mounted therein. Be careful not to touch any (nearby) optics!
  - The output coupler holder with the output coupler (fig. 5 (9)) and the UV-filter (fig. 5 (17)) therein. Loosen the screw fig. 5 (11) to take out this holder.
  - The compensator (fig. 5 (19)) by loosening the screws fig. 5 (20).
  - If present the first signal/idler separator mirror by loosening the screw fig. 5 (22).
  - The VIS-filter (fig. 5 (18))

  Install the laser safety beam tube fig. 5 (5) and the laser safety beam shield fig. 5 (3).

- Direct the pump beam (at lowest possible intensity) through the centre of the entrance aperture of the versaScan. Adjust the legs of the versaScan housing that the pump beam passes through the versaScan and exit through the exit aperture. Fix the versaScan to the table.
  Remember that for a versaScan/BB/HE and for a versaScan/MB the OPO should be build up in some distance to the pump laser in order to protect the THG crystal of the pump laser from overlapping outgoing and back reflected 355 nm radiation. The distance between the THG crystal of the pump laser and the versaScan output coupler (figure 5 (9)) should be:

  Pulse length of the pump laser in [ns] x 15 cm

  This is usually fulfilled for a typical distance between pump laser housing and the versaScan housing of about 30 cm - 40 cm.

  Laser safety: Remember that the laser safety beam tube (fig. 5 (5)) and the laser safety beam shield (fig. 5 (3)) always have to be in place before the pump light enters the versaScan. Wear appropriate laser safety goggles against the 355 nm radiation.

- Begin the adjustment of the lens distance with minimum lens distance d and minimum pump energy. Slide the inner tube of telescope (fig. 6 (2)) to change the lens distance.

- Increase the lens distance d step by step until the beam diameter in some distance behind the versaScan is only a little bit bigger then direct behind the telescope. A white piece of paper can be used to watch the beam diameter at lowest pump energy.

Attention: The pump beam must not exhibit a focus. Focussing occurs if the chosen lens distance is too big.

- Once the divergence is pre-aligned place a beam stop in some distance behind the versaScan and set the pump energy to full power. Fine align the lens distance by taking burn patterns behind the telescope and in some distance (about 1 m) behind the versaScan.
  The lens distance is optimized when the divergence of the pump beam behind the telescope is minimized. This is the case when the beam diameter 1 m behind the versaScan is about 0.5 mm bigger then direct behind the telescope.
  If the horizontal pump beam divergence is different from the vertical (elliptical beam) then try to minimize the horizontal divergence. But do not allow the vertical to focus!
  Note that the divergence of most pump lasers will change with pulse energy and repetition rate. The final adjustment of lens distance has to be made with maximum pump energy.

  Danger: For **versaScan/BB/HE** and **versaScan/MB**: Do not allow the pump beam behind the telescope to be convergent! Convergent alignment of the telescope (= lens distance too big) could lead to damage the THG unit of the pump laser by the back reflection of the versaScan/BB/HE or the versaScan/MB output coupler.

- Fix the lens position with the setscrew (fig. 6 (8)).

- Check again the beam diameter and intensity (< 0.65 J/cm², recommended: 0.5 J/cm² - 0.6 J/cm²).

- Once the telescope is aligned first build in the BBO crystal to the versaScan and check if the pump beam is clipped by the crystal (see below). Then build in the other optics.

6.4 Adjustable periscope mirrors

Figure 7(a) shows a drawing of the adjustable periscope mirror holders in the versaScan. The mirror holders are shown in red while the other parts of the versaScan are shown in grey.

The periscope of the versaScan is already adjusted and the screws are fixed when it is delivered to the customer. No readjustment is needed during normal operation and after the versaScan once is installed. Although when changing periscope mirrors the mirror holders must be adjusted. The procedure for changing periscope mirrors is explained in chapter 6.4.1. The adjustment of the periscope is explained in chapter 6.4.2.

Laser safety: When opening the cover (e.g. for alignment) ensure that the laser safety beam shield (fig. 5 (3)) and the laser safety beam tube (fig. 5 (5)) is in place any time pump laser light is entering the versaScan! Otherwise harmful reflections from the tilted BBO crystal will put the user at high risk!

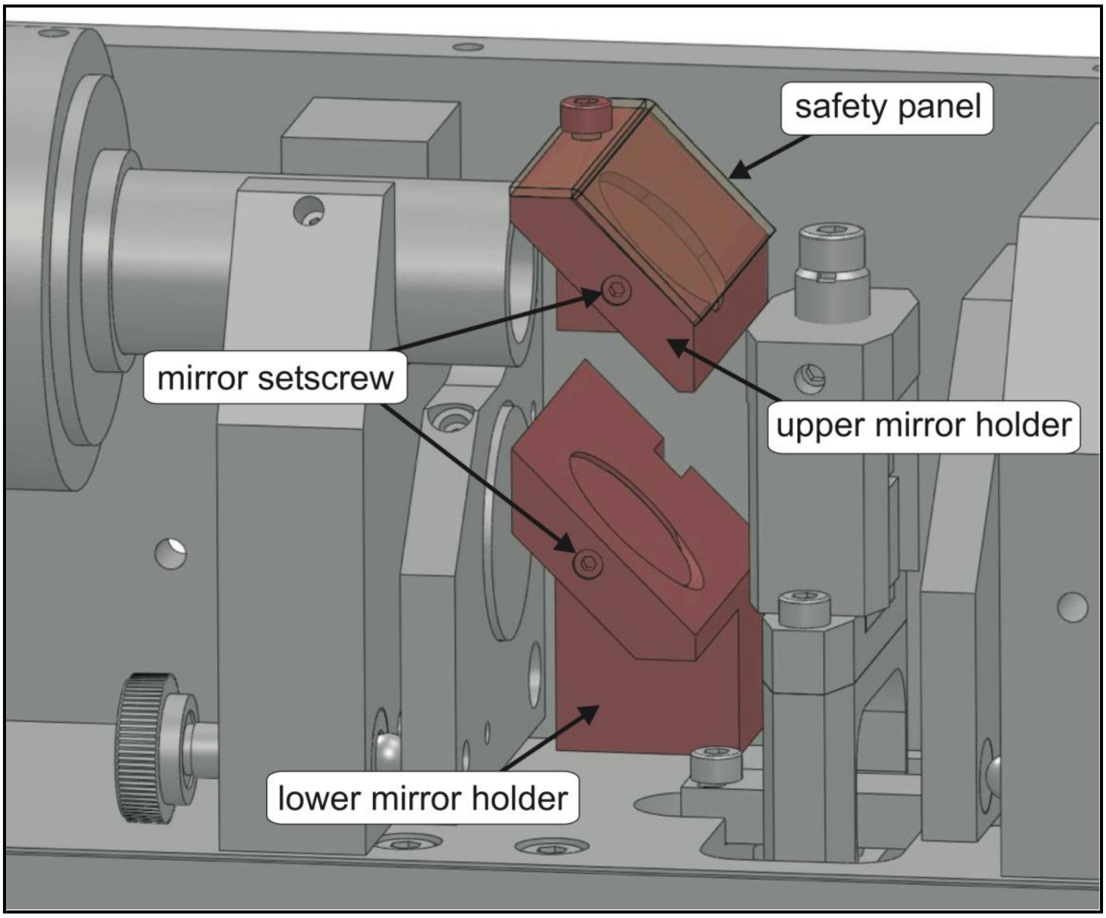


Figure 7(a): Adjustable periscope mirror holders (front view)

6.4.1 Changing periscope mirrors

To change the periscope mirrors first remove the laser safety beam shield (fig. 5 (3)). Then loosen and screw out completely the metric screws (M4, wrench size 3) that attach the periscope mirror holders to the rear panel of the versaScan.
On each of the screws two washers and one lock washer are mounted. These washers are needed on the one hand to make the mirror holders adjustable and on the other hand to fix them securely to the rear panel. For the correct arrangement of the washers refer to figure 7(b). The stack of washers consists of two normal washers with one lock washer between.
After removing the metric screws the mirror holders can be removed by pulling them out to the front of the versaScan perpendicular to the rear panel. Both mirror holders are set on pins so be careful when pulling them out of the system.
Next remove the small safety panel on the top of the upper mirror holder (refer to figure 7(a)). Use the small setscrews on the side of each mirror holder to remove the upper and the lower mirror and replace them by new ones. Put in the new mirror with the coated side facing down. The coated side is marked on the side of the mirror with a small **>** shaped sign. The tip of this sign points towards the coated side. On both mirror holders there are small edges on the opposite side of the setscrews which hold the mirrors safely in their position. Make sure that both mirrors are resting on these edges after assembly.

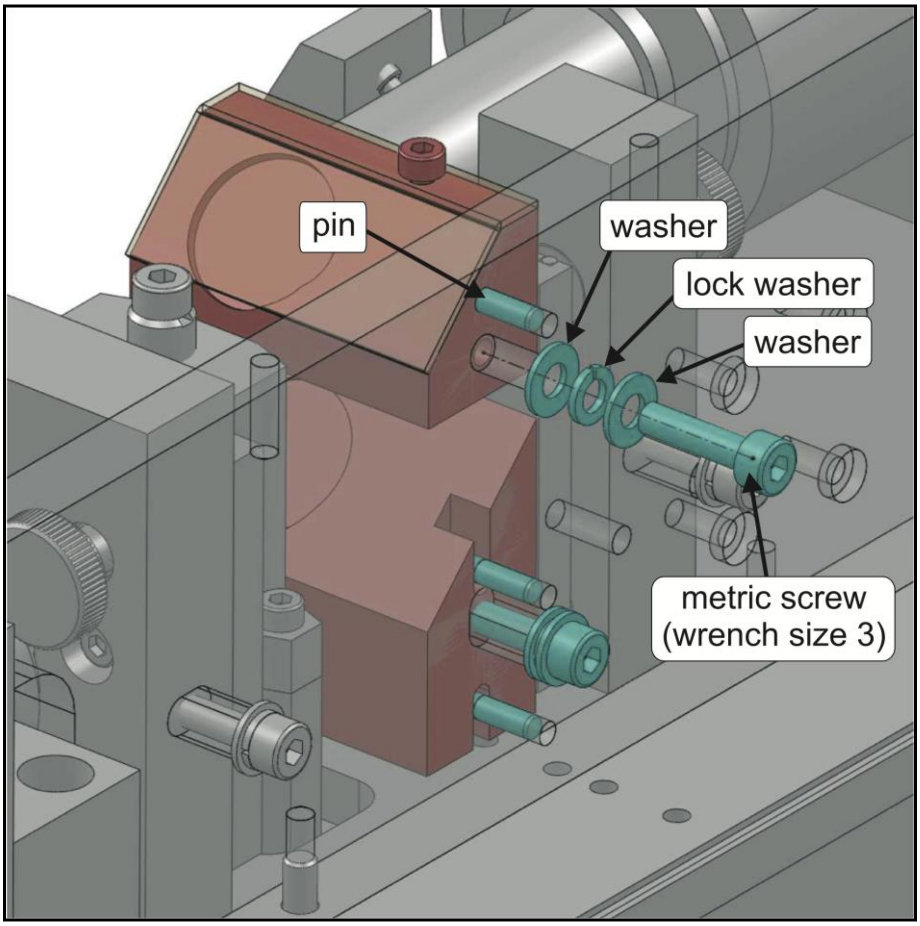


Figure 7(b): Adjustable periscope mirror holders (rear view)

Afterwards clip the mirror holders on the pins again and put in the setscrews with the washers in the rear panel. You do not have to assemble the metric screws completely as the holders need further adjustment. The procedure for the adjustment is explained in chapter 6.4.2. Due to safety reasons attach the small safety panel on the upper holder again before adjusting the upper mirror holder.

6.4.2 Adjusting the periscope mirror holders

If not already done take out all optics in the beam path behind the periscope mirrors (fig. 5 (16)). These are:

- The BBO crystal holder (fig. 5 (14)) if the BBO crystal (fig. 5 (12)) is mounted therein. Be careful not to touch any (nearby) optics!
- The output coupler holder with the output coupler (fig. 5 (9)) and the UV-filter (fig. 5 (17)) therein. Loosen the screw fig. 5 (11) to take out this holder.
- The compensator (fig. 5 (19)) by loosening the screws fig. 5 (20).
- If present the first signal/idler separator mirror by loosening the screw fig. 5 (22).
- The VIS-filter (fig. 5 (18))

If not already done install the laser safety beam tube fig. 5 (5). Set the pump laser to the lowest output energy possible at 355 nm for the following adjustment. I.e. use long pulse operation mode.

Make sure that the pump light hits the upper mirror of the periscope in the middle. If not adjust the telescope of the versaScan in the way like it is explained in chapter 6.3.

At first adjust the parallelism of the beam that exits the versaScan by turning the upper periscope mirror. Use a screen to check the position of the beam about 1 m behind the versaScan exit.

The position of the upper mirror holder is controlled by a pin in the rear panel of the versaScan. By loosening the metric screw the upper mirror holder can be turned around the pin and it is possible to adjust the pointing of the beam.

Laser safety: When the metric screw is removed from the rear panel completely the upper mirror holder can be turned around the pin completely! Harmful reflections from the tilted mirror holder will put the user at high risk when it is turned to the wrong side and the beam can exit the versaScan to the top!

The combination of the screw with two washers and one lock washer between makes it possible to turn the upper mirror holder a bit with some friction to the rear panel. Adjust the friction by loosening the metric screw a little bit. By turning the upper mirror holder it is possible to adjust the parallelism of the beam relative to the table.
When the beam is parallel to the table hold the upper mirror holder with one hand (i.e. press the holder with your thumb to the rear panel of the versaScan) and with the other hand use a metric Allen key (wrench size 3) to tighten the screw.

Important: While tightening the screw check that the position of the beam on the screen does not move!
Now the upper mirror holder is positioned correctly and must not be touched anymore during the further installation process!

The beam height through the BBO crystal is adjusted with the lower periscope mirror holder. The lower mirror holder is guided by two pins on the rear panel and one metric screw (refer to figure 7(b)). Do not screw out the metric screw completely as the lower mirror holder will not stay on the rear panel on its own!
The combination of metric screw and washers is the same as with the upper mirror holder. Loosening the screw a little bit to adjust the friction to move the mirror holder in vertical direction. The total range of vertical movement is 3 mm. Install the BBO crystal into the versaScan. (Refer to chapter 6.5 to install the crystal.)

Laser safety: High risk: Be very careful that the BBO crystal is NOT tilited against the pump beam. Otherwise harmful invisible pump light reflections from the tilted BBO crystal set the user to high risk of eye damage, because the laser safety beam shield fig.5 (3) is not in place. Use protective eyeware against the 355 nm pump radiation and execute the following adjustment with lowest possible energy out of the pump laser.

Watch the blue florescence of the pump beam on a white paper behind the crystal holder to adjust the beam height through the middle of the BBO crystal. You can use a transparent lens tissue in front of the versaScan as well in order to make the BBO crystal visible on the white paper.
Once it is adjusted keep the position of the lower mirror holder with one hand (i.e. press the holder with your thumb to the rear panel of the versaScan) and with the other hand use a metric Allen key (wrench size 3) to tighten the screw. While tightening the screw check that the position of the beam on the screen does not move.

Now fix the laser safety beam shield fig. 5 (3) and place a beam dump behind the versaScan and set the laser to the full power used for OPO pumping. Take burn pattern behind the BBO crystal (behind the versaScan housing).
If you see any clipping on top or bottom of the burn pattern adjust the height of the lower mirror holder again.

Now the adjustable periscope mirror holders are installed and adjusted correctly and should not be touched anymore during the following installation procedure!

6.5 Installation of the crystal

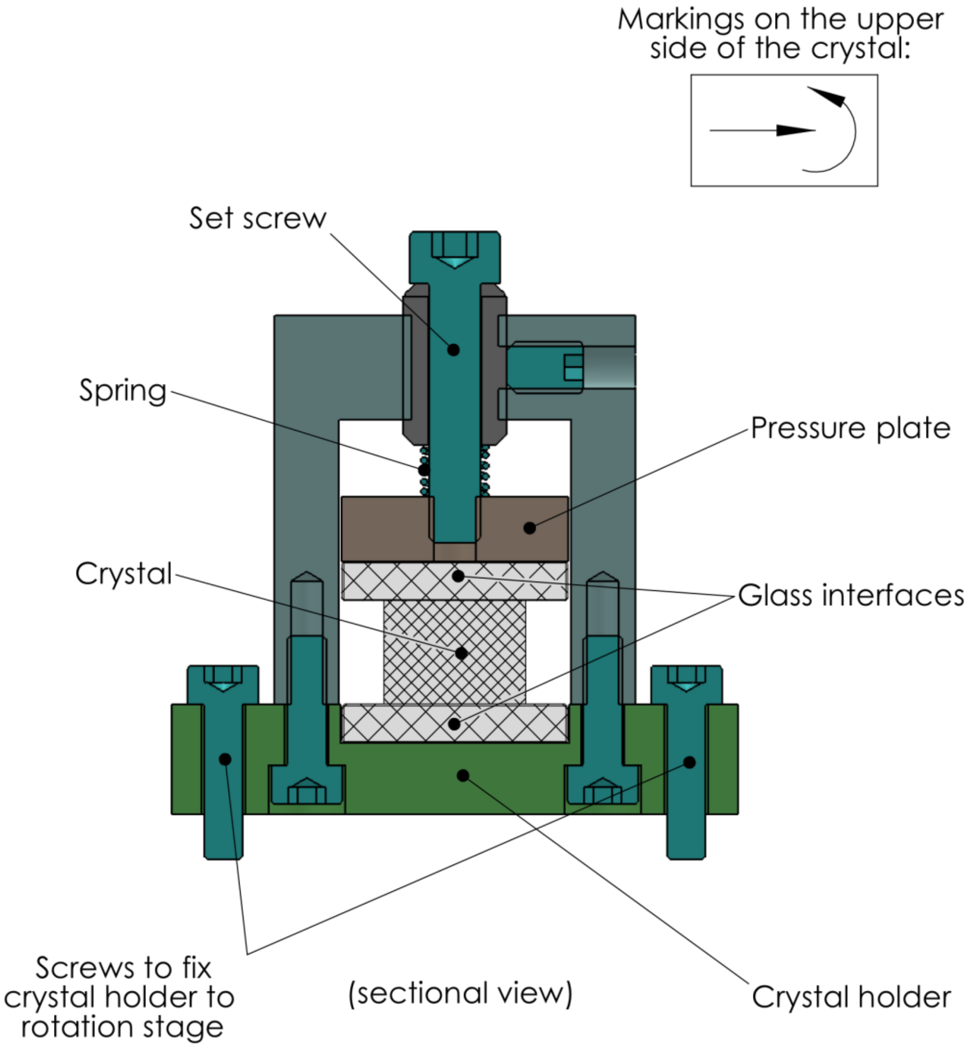


Figure 8: The crystal holder of the versaScan

Handle the crystal with great care! Do not touch the crystal! Use plastic tweezers which are not rigid to temporarily hold the crystals.

6.5.1 Build in the crystal to the crystal holder

First take out the crystal holder out of the versaScan: Remove the laser safety beam shield (fig. 5 (3)) above the crystal rotation stage (fig. 5 (13)) by loosening the 2 screws fig. 5 (4). Then loosen the 2 metric M3 screws (fig. 5 (14)) fixing the crystal holder to the rotation stage and take out the crystal holder. Be careful not to touch any nearby optics!

The BBO crystal is packed in a small plastic transparent transportation container. This container protects the crystal from mechanical shock during transport.

Note: Do not use the transportation container to store the crystal. It is appropriate only for the short storage during the transport. Place the crystal in a clean and dry place if it is not used for a longer time. Preferably use a desiccator for storage.

Centre the crystal in the crystal holder with the upper side to the spring & pressure plate inside the crystal holder (fig. 8). Fix the crystal in the holder by loosening the setscrew (metric M4) (fig. 8) carefully. The pressure of the spring is now holding the crystal.

Install the crystal holder to the rotation stage.
Fasten the laser safety beam shield (fig. 5 (3)) above the crystal rotation stage.

6.5.2 Check if the beam is clipped by the crystal

- If present take out the first signal/idler separator mirror (or the alternative polarizing beam splitter cube) by loosening the screw fig. 5 (22).
- Take out the output coupler holder with the output coupler (fig. 5 (9)) and the UV-filter (fig. 5 (17)) therein as well. Loosen the screw fig. 5 (11) to take out this holder. If the OPO resonator is already aligned it is alternatively possible to take out the UV-filter only by loosening the setscrew figure 5 (17a).
- Illuminate the crystal with the pump beam at the **lowest power** available and watch the transmitted pump beam with a white paper sheet. The beam should pass through the middle of the crystal.
- Rotate the crystal with the micrometer screw (fig. 5 (15)) or if present with the optional motor. The beam should not be clipped for the tilted crystal.
  Laser safety: The laser safety beam shield (fig. 5 (3)) and the laser safety beam tube (fig. 5 (5)) must be in place. Harmful reflections from the tilted BBO crystal will otherwise put the user at high risk!
  Be aware that the full angle tuning range of the crystal is possible for the motor only if the micrometer is screwed out completely (26 mm on scale). Vice versa the full angle tuning range can be accessed by the micrometer only if the motor is moved “out” completely. In the Scanmaster software click the button “Out” in “Manual Control” to move out the motor.
  Only for versaScan/BB and versaScan/BB/HE: Be aware that it is possible to tilt the crystal much more than needed that the beam will be clipped for extreme tilt angles. For this test it is sufficient to tilt the crystal between 7 mm and 18 mm on the scale of the micrometer screw or between -1,300,000 counts and + 1,300,000 counts with the motor.
- If the beam is clipped reposition the whole versaScan housing by adjusting the legs.
  A small re-adjustment can be done by loosening the three screws (fig. 5 (2)) of the telescope and adjust the position of the telescope.

6.5.3 Correct the crystal position to obtain the whole tuning range

The typical tuning range is: < 410 nm – > 2630 nm. If the tuning range is shifted it is necessary to tilt the crystal a little bit inside its holder.
In order to do this remove the crystal holder out of the versaScan and tilt the crystal with soft plastic tweezers inside the holder. Do not use force to tilt the crystal inside the holder. If you need force tighten the setscrew (fig. 8) to lift up the pressure plate (fig. 8) above the crystal and loosen the crystal. Then tilt the crystal and then loosen the setscrew again to fix the crystal with the pressure plate.
Then install the holder (with the crystal in it) to the rotation stage and check again if the beam is clipped by the crystal (see above). Then check the tuning range again.
Laser safety: Do not forget to fix the laser safety beam shield (fig. 5 (3)) ALWAYS BEFORE switching on the pump light.

6.5.4 Cleaning the crystal

Refer to “10.2 Cleaning optics”. Never use acetone to clean the BBO crystal!

6.6 The compensator crystal

Note: The output beams will shift as the crystal is rotated due to the angle tuning of the BBO crystal and its dispersion. This beam shift is a horizontal parallel beam shift which reaches max. 2.2 mm. There is no angular deviation.

However in some applications it may be useful to minimize the beam shift of the versaScan. In this case the compensator should be installed.

Note: The compensator is an uncoated quartz crystal. The versaScan beam will be attenuated by at least 8 percent.

6.6.1 Installation of the compensator crystal

- Remove the compensator holder from its rotation stage: Hold the compensator holder with your hands and loosen the two M3 screws fig. 5 (20) at the top.
  Be careful not to touch any nearby optics!

- Insert the compensator crystal in the holder and fix it gently with the set screw in the middle of the top side of the compensator holder.

- Install the compensator holder to its rotation stage.

6.7 Option M

The Option M is a motorization add-on for the versaScan and the optional uvScan to automate the wavelength tuning.

6.7.1 Unpacking the Option M

The Option M for the versaScan consists of:

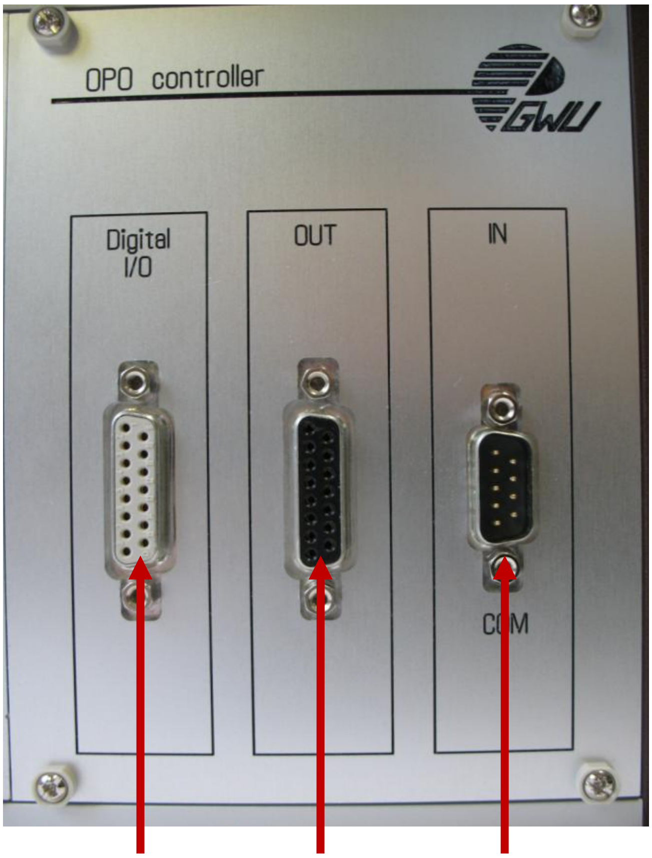
- 1pc. controller-box
- 1pc. mains lead
- 1pc. RS232-cable
- 1pc. SubD-15 cable
- 1pc. software CD
- optional 1pc. SubD-25 cable if the controller supports a uvScan

EMC compliance to FCC rules: Only use the above listed original cabling for all the connections to the OPO controller-box in order not to breach the electromagnetic compatibility (EMC) of the device(s) stated in the chapter 3.1 “EMC of the Option M”.

The DC-Motor(s) is (are) already mounted in your device(s) if the Option M is ordered.

6.7.2 Connecting the Option M

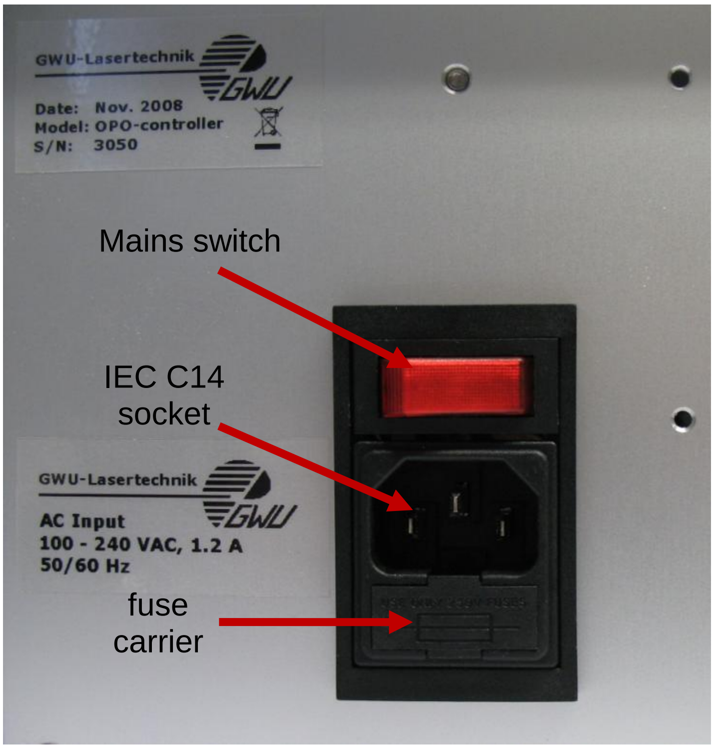
The terminal board is equipped with the following connectors:



Connect a COM-Port of your PC to the connector RS-232 “IN” with the provided null modem cable.
Use the 15-pin Sub-D cable to connect the OPO with the controller.
The Digital I/O Port can be used for optional remote control of the OPO-unit. Please refer to the software manual for further information about remote control options.

If the optional uvScan is present as well connect the OUT-terminal of the uvScan controller panel with the uvScan using the provided IEEE 25-pin Sub-D cable.

The backside of the controller box:



The controller box is operated with mains power 100-240VAC, 50/60 Hz. Connect the IEC C14 socket with a IEC C13 line plug and a appropriate wall plug for your country on the other end.
There is a fuse carrier equipped with two 1,6A slow-blow fuses (5x20mm T1,6A 250V AC) integrated into the IEC C14 socket.
As well the mains switch is mounted above the socket.

! Do not switch off mains power before the OPO software on your PC is shut down !

7 Resonator alignment of the versaScan/BB

Recommended equipment: HeNe-Laser, beam steering optics for HeNe

The versaScan/BB has to be set up with all optics built in except the UV-filter (fig. 5 (17)) (by loosening the set screw figure 5 (17a)) and the VIS-filter (fig. 5 (18)) and the compensator (fig. 5 (19)) and the first dichroic signal/idler separator mirror (fig. 5 (22)) have to be removed.
Laser safety: The laser safety beam shield (fig. 5 (3)) and the laser safety beam tube (fig. 5 (5)) must be in place. Harmful reflections from the tilted BBO crystal will otherwise put the user at high risk!

- Turn off the pump laser or block the pump beam.
- Direct the HeNe beam from the exit side through the versaScan/BB in the opposite direction to the pump beam.
- Put a paper screen with a small hole between HeNe and versaScan/BB.
- Observe the back reflections from the resonator mirror surfaces (see fig. 9). Note: The output coupler is wedged. You will see 2 reflections from the output coupler. The stronger reflection is the one from the coated surface when using a visible alignment laser.
  Tilt the crystal by turning the micrometer (fig. 5 (15)) or the optional motor to get rid of the crystal reflections, which are not of interest.

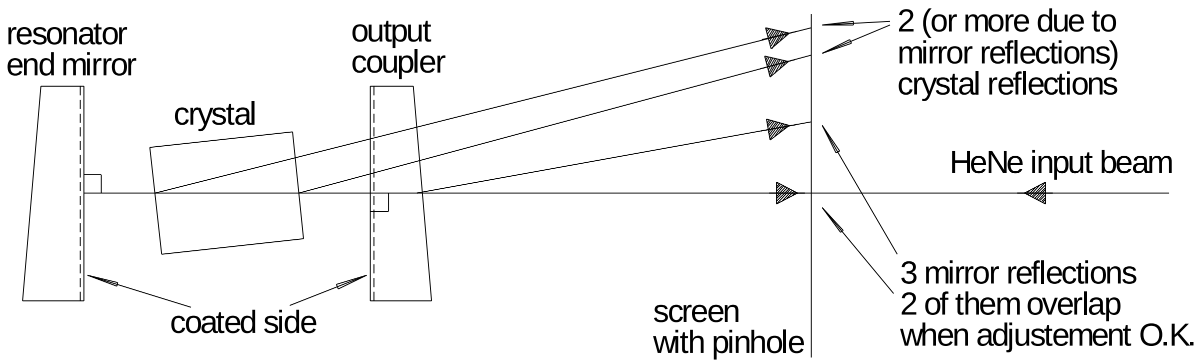


Figure 9: HeNe reflections from the well aligned versaScan cavity

The coated surfaces of the mirrors have to be aligned parallel with respect to each other.

- Adjust the mirrors in a way that the two reflections from the coated mirror surfaces are superimposed with the input beam (see fig. 9). In this case you may notice an interference pattern on the screen around the pinhole.
- Install the UV-filter (fig. 5 (17)) to the output coupler holder of the versaScan/BB.
- Turn on the pump laser again and select a reasonable pump energy level (0.45 J/cm² - 0.6 J/cm²).
- Tilt the crystal with the micrometer (fig. 5 (15)) or if present with the optional motor.

Now the versaScan/BB should oscillate within a certain angle range of the crystal. If not the optical cavity is not aligned properly. Repeat the mirror adjustment procedure.

Once oscillation occurs the versaScan/BB will probably require further optimization (refer to “7.1 Optimizing the versaScan/BB output” described below).

Note: It is possible to align the optical cavity without using a HeNe-laser.
In this case you select a reasonable pump energy level (0.45 J/cm² – 0.6 J/cm²) and adjust only one of the two resonator mirrors until the versaScan/BB begins to oscillate.
However, this method can possibly require some patience and it is strongly recommended to carry out the procedure “Optimising the versaScan/BB output” afterwards.

7.1 Optimizing the versaScan/BB output

Required equipment: Protective eyewear against the invisible idler radiation (710 nm – 3000 nm), IR sensitive detector card

To optimize the versaScan/BB output the optical cavity needs a final precise alignment by means of adjustment of the resonator mirrors.

Laser safety: The laser safety beam shield (fig. 5 (3)) and the laser safety beam tube (fig. 5 (5)) must be in place. Harmful reflections from the tilted BBO crystal will otherwise put the user at high risk!

7.1.1 Collinear alignment: Overlapping signal and idler beam

- First the signal/idler separation optics have to be removed from the versaScan: Take out the VIS-filter (fig. 5 (18)) and the first dichroic signal/idler separator mirror by loosening the screw figure 5 (22).
- Attenuate the pump until the versaScan/BB oscillates with only low output power (< 5 mJ/pulse).
- Put the VIS-filter in the versaScan/BB output beam.
- Use the IR sensitive card to check the idler beam direction behind the OPO. **DANGER:** Be careful with the reflection of invisible radiation from the detector card and the filter!
- Remove the VIS-filter.
- First adjust the signal beam towards the idler beam by adjusting both mirrors around the horizontal or the vertical axis.
- Then fine-adjust only one mirror (input mirror or output coupler) until the size of the visible signal spot is minimized. This can be observed best about 2 m behind the versaScan/BB.
- Finally observe the idler beam direction again. Repeat the adjustment procedure above until the signal and the idler radiation are collinear.

7.1.2 Alternative alignment: Overlapping signal and pump beam

If there is no IR sensitive detector card available it is alternatively possible to overlap the signal and the pump beam behind the OPO. However the above described method to overlap signal and idler is more accurate since the birefringence of the BBO crystal leads to a beam walk off of the pump beam against the signal and idler beams resulting in a horizontal side wards displacement of the pump beam against signal and idler of about 1 mm.

- To overlap the signal and the pump beam the filters (fig. 5 (17)) and (fig. 5 (18)) have to be removed from the versaScan. Loosen the set screw figure 5 (17a) to take out the UV-filter.
- Take out the first dichroic signal/idler separator mirror by loosening the screw figure 5 (22) as well.
- Attenuate the pump laser until the pump beam is just visible on a white business card.
- Observe the pump beam direction behind the versaScan/BB and mark the pump beam spot on a screen in a distance of at least 1 m behind the versaScan/BB.
- Now raise the pump power until the versaScan/BB oscillates with low output power (< 5 mJ/pulse).
- First adjust both versaScan/BB resonator mirrors that the signal beam approaches the pump beam mark on the screen until the signal beam is at this mark.
- Then fine-adjust only one mirror (input mirror or output coupler) until the size of the visible signal spot is minimized observed on the screen.
- Finally observe the signal beam direction again. Repeat the adjustment procedure above until the signal points towards the mark on the screen and its spot size is minimized.

8 Resonator alignment of the versaScan/MB and the versaScan/BB/HE

Recommended equipment: HeNe-Laser, beam steering optics for HeNe

The versaScan has to be set up with all optics built in except the UV-filter (fig. 5 (17)) (by loosening the set screw figure 5 (17a)) and the VIS-filter (fig. 5 (18)) and the compensator (fig. 5 (19)) and the first dichroic signal / idler separator mirror (fig. 5 (22)) or the alternative polarizing beam splitter cube have to be removed.
Laser safety: The laser safety beam shield (fig. 5 (3)) and the laser safety beam tube (fig. 5 (5)) must be in place. Harmful reflections from the tilted BBO crystal will otherwise put the user at high risk!

At first align the output coupler (fig. 5 (9)) only:

DANGER: Perform the following alignment procedure of the output coupler very careful. The THG stage of the pump laser may be damaged if the back reflection of the versaScan/MB or the versaScan/BB/HE output coupler is clipped by an optic therein!
As well the specified versaScan beam pointing stability when changing the versaScan wavelength is only maintained for a perfect collinear back reflection of the pump beam by the versaScan output coupler.

- Use a pin to pierce a pinhole in a sheet of black photo paper. Place and fix the photo paper between the pump laser and the versaScan with the black side towards the pump laser and the white side towards the versaScan. If you do not have such photo paper it is possible to use a business card or some thick paper which prevents the pump laser beam from shining through.
- Turn on the pump laser and attenuate it until the 355 nm pump beam is just visible on a white business card.
- Arrange the photo paper screen that the pinhole is in the middle of the pump beam.
- Observe the back reflections from the versaScan at the photo paper screen. Adjust the output coupler (fig. 5 (9)) until its back reflection is collinear with the input beam and runs back through the little hole in the paper screen.
- Turn off the pump laser or block the pump beam.

DANGER: Now the output coupler is aligned. DO NOT TOUCH the output coupler alignment screws any more in the future unless you are performing a complete new set up or alignment of the versaScan or unless you have to do this because the setup or beam pointing of the pump laser has changed. Changing the direction of the back reflection of the versaScan/MB or the versaScan/BB/HE output coupler towards the pump laser may damage the pump laser THG stage!

Now align the resonator end mirror (fig. 5 (7)) only:

- Turn off the pump laser or block the pump beam.
- Direct the HeNe beam from the exit side through the versaScan in the opposite direction to the pump beam.
- Put the photo paper screen with the pinhole between HeNe and versaScan with the white side towards the versaScan.
- Observe the back reflections from the resonator mirror surfaces (see fig. 9). Note: The output coupler is wedged. You will see 2 reflections from the output coupler. The stronger reflection is the one from the coated surface when using a visible alignment laser.
  Tilt the crystal by turning the micrometer (fig. 5 (15)) or the optional motor to get rid of the crystal reflections which are not of interest.
- Adjust only the resonator end mirror (fig. 5 (7)) that its reflection is superimposed with the strong reflection of the coated surface of the output coupler. In this case you may notice an interference pattern on the screen around the pinhole.
- Put in the UV-filter (fig. 5 (17)) to the output coupler holder of the versaScan.
- Turn on the pump laser again and select a reasonable pump energy level (0.45 J/cm² - 0.6 J/cm²). Now the versaScan should oscillate. If not adjust the reflection of the resonator end mirror a little bit besides the reflection of the output coupler that the reflection of the output coupler is between the pinhole and the reflection of the resonator end mirror. In case of a versaScan/BB/HE tilt the BBO crystal as well with the micrometer (fig. 5 (15)) or if present with the optional motor.
- Finally fine align the resonator end mirror so that the spot size of the visible OPO output beam is minimized observed on a black screen in a distance of at least 1 m behind the versaScan.
- Only for the versaScan/MB to ease the final fine alignment of the upper fine pitch screw[4] of the resonator end mirror which tilts the mirror around the horizontal axis (leads to a vertical beam displacement):
  The lower fine pitch screw is much more sensitive and it is much easier to recognize the best alignment of this screw. Thus it is recommended first to tilt (= misalign) the lower fine pitch screw a bit that a sidewards tail is visible in the OPO beam observed on the black screen in > 1 m distance behind the OPO. Then align the upper fine pitch screw that this sidewards tail goes on average exactly sidewards (not sidewards up and not sidewards down). It may be that the upper part of the tail goes a little bit upwards and the lower part of the tail goes a little bit downwards. Align the upper fine pitch screw in a way that the middle part of the tail points exactly sidewards.
  Then align the lower fine pitch screw to achieve the minimum horizontal beam diameter observed on the black screen in > 1 m distance behind the OPO.

Now the versaScan/MB or versaScan/BB/HE is aligned properly with a collinear alignment. This means the pump, the signal and the idler radiation are collinear. There is no need to perform a procedure like in chapter 7.1 “Optimizing the

[4] The upper fine pitch screw of the resonator end mirror is the fine pitch screw behind the laser safety beam tube (fig. 5 (5)).

versaScan/BB output" since the alignment of the back reflection of the output coupler ensures the collinear alignment. If you want you can double-check the collinear alignment of the versaScan like described in chapter 7.1. But note for the versaScan**/MB** that the birefringence of the BBO crystal leads to a beam walk off of the signal beam against the idler beam. Thus for the versaScan**/MB** you should rather check that the idler wave and the pump wave are collinear behind the OPO.

DANGER: Always when changing the alignment of the output coupler of the versaScan/MB or the versaScan/BB/HE double check the back reflection of the output coupler! E.g. check at the pinhole placed between the pump laser and the OPO like described above with the procedure to align the output coupler. A changed direction of the back reflection of the output coupler towards the pump laser may damage the pump laser THG stage!

Note: It is possible to align the optical cavity without using a HeNe-laser. In this case first you adjust the output coupler like described above. Then you select a reasonable pump energy level (0.45 J/cm² – 0.6 J/cm²) and adjust the resonator end mirror until the versaScan begins to oscillate. Finally fine align the resonator end mirror so that the spot size of the visible OPO output beam is minimized observed on a black screen in a distance of at least 1 m behind the versaScan.

Note: This note is relevant for the versaScan**/MB** only! It is **not** relevant for the versaScan/BB/HE:
The typical beam shape of the versaScan/MB in some distance behind the versaScan/MB is elliptical. The reason is the minimized divergence of the versaScan/MB in the horizontal plane (typical < 0.3 mrad). The versaScan/MB is aligned properly when the beam shape > 2 m behind the versaScan/MB is a vertical narrow line. If the line is broadened in the horizontal this broadening means a broadening of the versaScan/MB linewidth. The versaScan/MB is aligned best and has purest narrow linewidth when the stray radiation beyond this line is minimized and the line is as narrow as possible.

9 Daily use

9.1 Start up

Ensure that the surfaces of the optics are free from dust. Particles burned onto the dielectric coatings of the mirrors or the crystal surfaces can lead to reduced output energies.
Dust particles and pollutants should be removed by blowing clean air onto the surfaces. Never blow your (wet) breath onto the optics!

Close all the covers of the versaScan before switching on the pump laser! If the covers are partially open:
Laser safety: Ensure that the laser safety beam shield (fig. 5 (3)) and the laser safety beam tube (fig. 5 (5)) is in place any time pump laser light is entering the versaScan! Harmful reflections from the tilted BBO crystal will otherwise put the user at high risk!

Refer to the manual of the pump laser for the start up procedure of the pump laser. We recommend to allow the pump laser to warm up first (typically 15 min with the flashlamps at full power).
Typically the first shots of the pump laser are hotter than usual if you open an intracavity shutter of the pump laser or if you switch it to Q-switch operation with full flashlamps power. We recommend NOT to use these first shots for the versaScan. Reduce the flashlamps drive a little bit before opening the shutter or switching the laser into Q-switch operation. Then rise the flashlamps power again. Or block these first shots in front of the versaScan.

9.2 Operation

If the versaScan output stability or energy is poor we recommend to fine adjust the phasematching angles of the SHG and THG crystals of the pump laser at first to reach the maximum 355 nm output. The final fine adjustment of these SHG and THG stages should be done after the pump laser has warmed up well with the pump laser light going through the SHG and THG stages for more then 1 hour at full power.

9.2.1 Wavelength tuning

Use the micrometer (fig. 5 (15)) for wavelength adjustment to change the versaScan output wavelengths. The scale on the micrometer is not fixed to the output wavelengths. The relation between the scale on the micrometer and the versaScan wavelength is a non-linear function.
Once the versaScan is set up and aligned it is possible to calibrate the scale on the micrometer: Just let the system warm up enough and measure the (signal-) wavelength and note down the corresponding micrometer position. When measuring the signal wavelength the corresponding idler wavelength can be obtained through the following relation (see as well fig. 2 in chapter 3 “Specifications of the versaScan”):

$$\mathbf{1/\lambda_{idler} = 1/\lambda_{pump} - 1/\lambda_{signal}}$$

Which follows directly out of the energy conservation:

$$\omega_{pump} = \omega_{signal} + \omega_{idler}$$

This calibration is valid as long as the alignment and set up of the pump laser and the versaScan has not changed.
The versaScan wavelength is depending on the beam direction of the three interacting waves (pump, signal, idler) relative to the crystal optical axis. Thus the angle under which the crystal is fixed inside the holder as well as the pump beam direction and the alignment of the versaScan resonator mirrors[5] are affecting the output wavelengths.

The typical pointing stability specification of many pump lasers (100 µrad) is such that if the pump laser changes its beam direction by 1 time its specified range then the versaScan wavelength changes typically by about 1 time the versaScan line width. (The actual versaScan line width is mostly depending on the actual versaScan wavelength, see fig. 3 and fig. 4).
By experience the pointing direction of the pump laser changes slowly by time (in particular when warming up). This means there is no shot to shot wavelength change but a slow drift during hours of operation may occur. Up to now we know only one extremely compact pump laser (specified pointing stability: ± 200 µrad) where a shot to shot wavelength jitter of the OPO has been observed.

The wavelength drift due to temperature change of the BBO crystal is negligible since the temperature tuning of BBO is extremely low. A temperature change of 15 to 25 °C will lead to a wavelength drift of only 1 time the linewidth of the versaScan. If such a big room temperature change will occur the wavelength change due to other effects which affect mainly the beam directions (mechanical, laser pointing) will be bigger.
Only during the first 5 minutes the pump light is entering the versaScan the wavelength may drift a little bit due to warming up the crystal. This effect is nearly not noticeable for low power 10 Hz systems and may score up to approximately 1 time the linewidth all for systems with high pump power and/or high repetition rates > 10 Hz.

9.2.2 Motorized tuning

For the GWU versaScan and the GWU premiScan automated wavelength tuning is available ("Option M"). If the motorized tuning is installed it is still possible to change the wavelength of the versaScan with the micrometer fig. 5 (15) as well.
As a further option a lambdameter ("lambdaScan") can be added which integrates within our user friendly software. The lambdaScan is providing convenient absolute wavelength control and full automated OPO wavelength calibration.

Be aware that the full wavelength range for the motorized tuning is available only if the micrometer fig. 5 (15) is screwed out completely (26 mm on scale).

[5] Which are defining the signal beam direction

Vice versa the wavelength range can be accessed by the micrometer only if the motor is moved “out” completely. In the Scanmaster software click the button “Out” in “Manual Control” to move out the motor.
The versaScan mechanic is allowing 2 different positions to attach the motor leading to different crystal tuning angle ranges. The full angle range of the crystal rotation stage is accessible by the motor if the motor is placed in the position signed for the versaScan**/MB** in figure 5. In the position signed for the versaScan**/BB** the motorized angle range is somewhat smaller.
The default motor position for the versaScan**/BB** is allowing the full wavelength tuning range for the versaScan**/BB** and the versaScan**/BB/HE**. If you place the motor in the default position for the versaScan**/MB** the OPO can do a higher maximum tuning speed but the wavelength repeatability/accuracy is poorer.
In case of a versaScan**/MB** only the default position of the versaScan**/MB** is providing the full wavelength tuning range for the versaScan**/MB**. The wavelength accuracy of the versaScan/MB can be improved by placing the motor to the default position of the versaScan/BB but then the versaScan/MB tuning range is limited/narrowed.

9.2.3 Separation of signal and idler

The versaScan is generating two different wavelengths: The signal wave and the idler wave. In other words the versaScan is splitting single pump photons into two photons: The photons with the higher photon energy are forming the signal wave (405 nm – 709.4 nm) and the photons with the lower photon energy are forming the idler wave (709.5 nm – 2550 nm). Both waves are emitted from the versaScan simultaneously through the same exit aperture.

In order to separate signal and idler there are the following possibilities:

9.2.3.1 VIS-filter

The VIS filter (∅ 25 mm x 3 mm, black colour) is delivered together with the versaScan. The VIS filter is absorbing the visible signal beam in the range 405 nm to 690 nm allowing to use pure idler radiation in the IR range 730 nm to 2630 nm.
The VIS filter can be mounted to the exit aperture of the versaScan (fig. 5 (18)).

Separation quality:
The VIS-filter is suppressing the signal wave better then 10000:1 for the idler wavelength range 735 nm to 2630 nm.

Laser safety: Take care! The versaScan output is no more visible behind the VIS-filter but it is still very harmful (invisible CLASS 4 laser radiation!). Use laser safety goggles against this invisible IR radiation (680 nm – 3000 nm)!

9.2.3.2 Dichroic separators

Dichroic signal/idler separator mirrors are available as an option. A set consists of two mirrors (fig. 5 (21)) which are reflecting the signal wave (405 nm - 709 nm) under 45° and transmitting the idler wave (710 nm – 2630 nm).

To insert dichroic signal/idler separator mirrors put the mirror holders to the pins and fix them with the setscrew fig. 5 (22).
It is recommended to put the VIS-filter (fig. 5 (18)) into the idler branch to clean up the transmitted idler beam from remaining signal radiation. Be aware that the transmission of the VIS-filter in the wavelength range 710 nm – 740 nm varies between only 28 % at 710 nm up to 87 % at 740 nm. The transmission of the VIS-filter is higher than 90 % at 750 nm – 2200 nm.

Separation quality of this set up:
idler wave: Better then 10000:1 between 735 nm and 2630 nm (behind VIS-filter).
signal wave:
versaScan/BB and versaScan/BB/HE: Better then 300:1 between 405 nm and 620 nm
versaScan/MB: Better then 500:1 between 405 nm and 620 nm

Laser safety: If the invisible idler beam is not used block it with a suitable beam stop (available from GWU). Take care! The idler beam is not visible but it is still very harmful (invisible CLASS 4 laser radiation!). Use laser safety goggles against this invisible IR radiation (680 nm – 3000 nm)!

9.2.3.3 Polarizing beam splitter cube

Available as an option only for the midband OPO versaScan**/MB** operable only in the wavelength range 600 nm – 870 nm.
For the versaScan/MB the signal and idler radiation is polarized different: The signal radiation is polarized vertical (like with the /BB models) while the idler radiation is polarized horizontal. This aided already the separation by the standard dichroic signal/idler separator mirrors. Even when using them near and at degeneracy the reflection of the signal wave of the versaScan**/MB** is still much higher then the reflection of the idler wave even if their wavelengths are the same.
But a separation quality of better then 500:1 near degeneracy in the wavelength range 620 nm – 735 nm is only possible using the polarizing beam splitter cube for the versaScan/MB.

Danger: The polarizing beam splitter cube can only be used in the wavelength range 600 nm – 870 nm in which the signal beam is visible with "red" colour. The polarizing beam splitter cube may be damaged if it is illuminated with the OPO radiation outside the "RED" (600 nm – 870 nm) wavelength range. I.e. "orange" or "green" OPO light may damage the polarizing beam splitter cube! Always set the OPO wavelength into the allowed wavelength range before switching on the pump laser light! If you use the motorized wavelength tuning ("Option M") always command the OPO into the wavelength range 600 nm – 870 nm before switching on the pump laser light!

Laser safety: Switch off the pump laser light before the insertion of the polarizing beam splitter cube assembly!

The polarizing beam splitter cube is substituting the first of the 2 dichroic signal/idler separators. Thus to insert the polarizing beam splitter cube take out the first dichroic signal/idler separator by loosening the screw fig. 5 (22). Put in the beam splitter cube

to the former place of this dichroic signal/idler separator mirror. Pins in the base plate of the versaScan/MB help to position the polarizing beam splitter cube.
Be careful not to touch any optics with your fingers! It is recommended to wear clean gloves. Once optical components are touched they should immediately be cleaned. Refer to chapter 9.2 “Cleaning optics”.

Conclusion: The best possible separation of signal and idler is provided by:

Wavelength range	Recommended separation optics for versaScan/MB
400 nm – 620 nm	Dichroic mirrors
620 nm – 750 nm	Polarizing beam splitter cube
750 nm – 2630 nm	VIS-filter (with or without dichroic mirrors)

Tip: Above 700 nm (between 700 nm and 709.4 nm) the reflection of the remaining second dichroic separator may be less then 95 % (but is better then 80 %). To avoid these losses this dichroic separator mirror can be taken out. Since there is no outlet to couple out the signal radiation out of the versaScan/MB housing you need to take off the rear cover plate of the versaScan/MB or drill a hole into it.

9.2.3.4 Non-collinear versaScan alignment

If the versaScan is well aligned like described in chapter 7 or 8 then the signal and idler waves are collinear (overlapping spatial).
It is possible to align the versaScan non-collinear as well. Then the signal and idler waves are not collinear and both beams are separated in some distance behind the versaScan.
Attention: Only for versaScan/BB/HE and versaScan/MB: You have to block the back reflection of the output coupler on a suitable beam stop in front of the pump laser when aligning non-collinear. This is only possible if the distance between pump laser and OPO is big enough. It is not recommended to use the non-collinear alignment on the versaScan/BB/HE or the versaScan/MB. It is recommended to align the output coupler like described in chapter 8 and use the delivered back reflection protection for the laser.
The specified beam pointing stability of the versaScan is only obtained for the collinear alignment. For non-collinear alignment the beam direction of the signal and idler wave may slightly change when changing the wavelength. Typically this change is less than the divergence of the beams such that it is not remarked by the user.
This non-collinear alignment can be achieved by tilting both versaScan resonator mirrors against the pump beam and then fine align only one of the two resonator mirrors until the size of the visible signal spot is minimized. This can be observed best on a black screen about 2 m behind the versaScan.

9.2.4 Degeneracy

“Degeneracy” defines the situation when the signal wavelength and the idler wavelength are the same. This is at the versaScan output wavelength of 709.4 nm which is just 2 times the pump wavelength.

9.2.4.1 versaScan/BB and versaScan/BB/HE

For the versaScan/BB and the versaScan/BB/HE it is not possible anymore to separate signal and idler at and near degeneracy since they can no more be distinguished. They are degenerated.
As well the different wavelengths separations described above (under 8.2.2) do not work properly near degeneracy between about 690 nm and 730 nm. The versaScan/BB(/HE) beam characteristics like the divergence (described above in 8.2.3) and the spectral behaviour are changing as well near degeneracy.
The linewidth of the broadband OPO versaScan/BB(/HE) is maximal at degeneracy reaching about 8 nm to 20 nm (mostly depending on pump pulse length).
But the versaScan/BB(/HE) output energy is typically about maximum at degeneracy.
The "degeneracy gap" (690 nm – 730 nm) does not mean that the versaScan is not operating at degeneracy. It means that the typical beam characteristic is changing and that it is no more possible to separate signal and idler making the output useless for many applications.

9.2.4.2 versaScan/MB

With the midband OPO versaScan/MB it is possible to separate signal and idler at degeneracy since they differ by polarization. As well the linewidth of the versaScan/MB is constant with about 4 cm^{-1} (for 7 ns pump pulse length) over the whole tuning range except near degeneracy where it may rise by 50%.
Only few optics need to be changed to upgrade the versaScan/BB or versaScan/BB/HE to the versaScan/MB.

9.2.5 versaScan beam characteristics

The signal beam is emitted divergent while most energy of the idler beam is emitted convergent forming a beam waist with about 1 mm diameter about 20 cm to 40 cm behind the versaScan.
In case of the midband OPO versaScan**/MB** this behaviour takes only place in the vertical plane. This means that for the versaScan/MB the signal wave is divergent and the idler wave is convergent only in the vertical axis while the signal and idler divergence is minimized in the horizontal (see chapter 3: "Specifications of the versaScan"). This means that the idler beam waist for the versaScan/MB is forming a horizontal line (instead of a round spot for the versaScan**/BB** or the versaScan/BB/HE) about 20 cm to 40 cm behind the OPO.
Be careful when placing optics near the beam waist of the versaScan. Many optics like mirrors with a metallic coating (Al, Ag, Au) may be damaged near the idler beam waist. Other (even coated) optics for **high power applications** (prisms, lenses, dichroic mirrors) are usually not damaged.
The idler beam waist can be observed by taking burn patterns behind the versaScan. If you let the signal beam exit collinear together with the idler wave then a weak burn pattern of the signal beam may be discovered around this beam waist as well. For the ideal collinear alignment of the versaScan the idler beam waist should be in the centre of the signal beam.
The signal energy density is typically just at the reaction threshold of the burn pattern photo paper. Thus sometimes the photo paper does not react on it. Or it reacts only at the intense parts of the signal radiation which are then just above the reaction

threshold of the photo paper forming a strange looking burn pattern because most of the beam is not comprised therein. We recommend to use a camera instead to analyze the real characteristic of the full versaScan output beam.

The versaScan**/BB** beam is round and flat top with a very smooth energy distribution. Only for pump lasers with a very unbalanced energy distribution in the beam this structure of the pump laser may be visible as well in the OPO beam. Structures in the pump beam which are smaller than 1 mm are flattened completely by the OPO.

In a bigger distance behind the OPO the versaScan**/MB** beams (signal and idler) are forming vertical lines because of their bigger divergence angle in the vertical plane. The versaScan/MB beam shape is flat-top as well but may contain some typical structure like few (1 vertical and 2 – 3 horizontal) narrow lines with low intensity. In most cases this structure is only faint depending on the pump laser. But this structure will occur and is typically strong when using a seeded narrow linewidth pump laser.

The versaScan divergence angles scale with the pump pulse duration. For relatively long pulses (7 ns – 10 ns) the OPO divergence is much less then for relatively short pulses (3 ns – 5 ns).

9.3 Shut down

Just switch off the pump laser. Refer to the manual of the pump laser for the shut down procedure. We recommend to let the internal cooling water of the pump laser circulate for some minutes after switching off the flashlamp flashing.

In case of the option M:
First exit the software “ScanMaster” and wait for the motor to access its home position. Then you can switch off the motor controller.

10 Maintenance

10.1 Precautions

Do not touch the optical components! Wear gloves or use weak plastic tweezers to hold optical components!

Ensure that the surfaces of the optics are free from dust. Particles burned onto the dielectric coatings of the mirrors or the crystal surfaces can lead to reduced output energies.
Dust particles and pollutants should be removed by blowing clean air onto the surfaces. It is recommended to do this any time the versaScan was not in use for more then 1 week or any time the cover of the versaScan was opened.
Never blow your (wet!) breath onto the optics!

If the versaScan will not be in use for a long period of time we recommend to store the BBO crystal in a clean and dry place. Preferably use a desiccator for storage.

From time to time it is recommended to take a burn pattern of the pump laser to observe the laser beam profile. Use black (exposed and processed) photo paper. Always place a transparent plastic bag around the burn pattern photo paper to avoid contamination of the optics with ablated dust powder. The plastic bags have to be free of any imprints on it (e.g. NO recycling sign imprinted). The laser ablation of the imprints will damage optics!
Direct the laser beam onto the photo paper (only one shot at one place).
DANGER: Be very careful with the reflection of the laser beam from the photo paper. Protect your eyes. Do not look at the photo paper when taking burn pattern!

From time to time with most pump lasers it is necessary to fine adjust the SHG and THG crystals. This should be done with the pump laser warmed up very well (after about 2 hours running time at full power).

10.2 Cleaning optics

Ensure that the surfaces of the optics are free from dust. Particles burned onto the dielectric coatings of the mirrors or the crystal surfaces can lead to reduced output energies.
Dust particles and pollutants should be removed by blowing clean air onto the surfaces. Never blow your (wet!) breath onto the optics!

If optics cleaning is necessary: To clean the BBO crystal surfaces Isopropyl-alcohol (IPA) or a mixture of alcohol and ether in the 1:1 ratio or trichlorethylen or trichlorethan on a soft lens tissue is recommended.
Never use acetone to clean the BBO crystals!
The other optics may be cleaned with fresh (water free) methanol on a soft lens tissue.

11 Troubleshooting

Problem	Solution
Spectral width is too large	• Adjust the versaScan cavity that the signal and idler waves are collinear • Lower the pump energy density e.g. by changing the telescope lenses (call GWU). Note: The output power will drop. • Adjust telescope focal length (refer to “6.3 Setup of the telescope”) • Take a pump laser which has longer pulse length. pump pulse duration has a strong influence to the versaScan linewidth and divergence! • Narrow the spectral width of the pump laser (i.e. use an injection seeder)
Bad beam profile	• Check the beam profile of the pump laser • Check the optics of the versaScan for any evidence of damage • Adjust the versaScan cavity
Divergence is to high	• Lower the pump energy density e.g. by changing the telescope lenses (call GWU). Note: The output power will drop. • Check pump laser divergence • Adjust telescope focal length (refer to “6.3 Set up of the telescope”) • Take a pump laser which has longer pulse length. pump pulse duration has a strong influence to the versaScan linewidth and divergence!
idler beam direction changes when changing the versaScan wavelength	• Adjust the versaScan cavity that the signal and idler waves are collinear
Tuning range is limited	• Refer to “6.4.3 Correct the crystal position to obtain the whole tuning range”
Output energy is not stable	• Fine adjust the SHG and THG stage of the pump laser until the generated 355 nm output of the pump laser is maximum • Check energy stability of the pump laser • Check pump energy. It has to be at least 3 times threshold for stable versaScan operation. But the pump energy density behind the telescope must not exceed 0.65 J/cm² for pump pulse duration > 4 ns or 0.6 J/cm² for pump pulse duration < 4 ns • Adjust the versaScan cavity • Check the optics of the versaScan for any evidence of damage

Problem	Solution
Output energy is too low	• Fine adjust the SHG and THG stage of the pump laser until the generated 355 nm output of the pump laser is maximum • Check pump energy. It has to be at least 3 times threshold[6] for stable versaScan operation. But the pump energy density behind the telescope must not exceed 0.65 J/cm² for pump pulse duration > 4 ns or 0.6 J/cm² for pump pulse duration < 4 ns • Adjust the versaScan cavity • Check the optics of the versaScan for any evidence of damage
versaScan does not oscillate (no versaScan output)	• Check polarization of the pump laser @ 355 nm. It has to be horizontal • Check the optics of your versaScan for any evidence of damage • Check pump energy. The pump energy density behind the telescope has to be higher than 0.45 J/cm² in a beam diameter bigger than 3 mm • Repeat the whole versaScan installation and adjustment procedure

In the case that you have problems with your GWU-OPO call our service engineers:

	Headquarter:	Technical Support:
	GWU-Lasertechnik GmbH	GWU-Lasertechnik GmbH
	Bonner Ring 9	Kohlenhofstrasse 10
	50374 Erftstadt–Lechenich	67663 Kaiserslautern
	Germany	Germany
Phone:	+49 2235/9 55 22-0	+49 631/303 88-99
FAX.:	+49 2235/9 55 22-99	+49 631/303 88-76
E-mail:	info@gwu-group.de	info@gwu-group.de

It is our job to make you satisfied!

[6] The OPO threshold is the pump energy at which the OPO begins to oscillate. To measure the threshold attenuate your pump laser until the OPO emission is barely visible. Measure the pump pulse energy at this point (= threshold).

12 Appendix A

Lens combinations used as standard up to 2010:

Table 3: Magnification of the pump beam diameter = lowering the energy density

Diameter magnification	Energy density lowered down to (factor)	Focal length [mm]		Lens distance [mm]	Comment
		f_1	f_2		
1 : 1.167	0.735	-150	175	25	
1 : 1.25	0,64	-100	125	25	Standard telescope
1 : 1.33	0,565	-75	100	25	
1 : 1.5	0,444	-100	150	50	
1 : 1.67	0,358	-75	125	50	
1 : 1.75	0,327	-100	175	75	
1 : 2	0,25	-75	150	75	
1 : 2.33	0,184	-75	175	100	

Table 4: Reduction of the pump beam diameter = rising the energy density

Diameter reduction	Energy density rises by (factor)	Focal length [mm]		Lens distance [mm]	Comment
		f_1	f_2		
1 : 0.857	1.36	175	-150	25	
1 : 0.80	1.56	125	-100	25	Standard telescope
1 : 0,75	1.77	100	-75	25	
1 : 0,667	2.25	150	-100	50	
1 : 0.60	2.79	125	-75	50	
1 : 0.571	3.06	175	-100	75	
1 : 0.5	4.0	150	-75	75	„self destroying“, the focus from the beam reflected by the plane surface of the 2nd concave lens is inside the 1st convex lens. [7]
1 : 0.429	5.43	175	-75	100	

These lenses have been the standard up to 2010. They are still available as non standard. These lens combinations exhibit a bigger change in energy density from step to step compared to the actual standard lens set (see chapter 6.3.1 “Possible lens combinations”). On the other hand this lens set covers a much wider range to change the energy density. So they may be useful in particular for non standard pump lasers.

Choose an appropriate set of telescope lenses in order to attain within the

target pump energy density = 500 mJ/cm² ... 550 mJ/cm².

At least try to stay within the

recommended pump energy density = 500 mJ/cm² ... 600 mJ/cm².

Never exceed the

allowed pump energy density = 450 mJ/cm² ... 650 mJ/cm².

[7] Way out: Orientate the curvature of the 2nd concave lens the other way round then standard! But be careful to pre-align the lens distance accurately **before** exposing it with the pump beam!