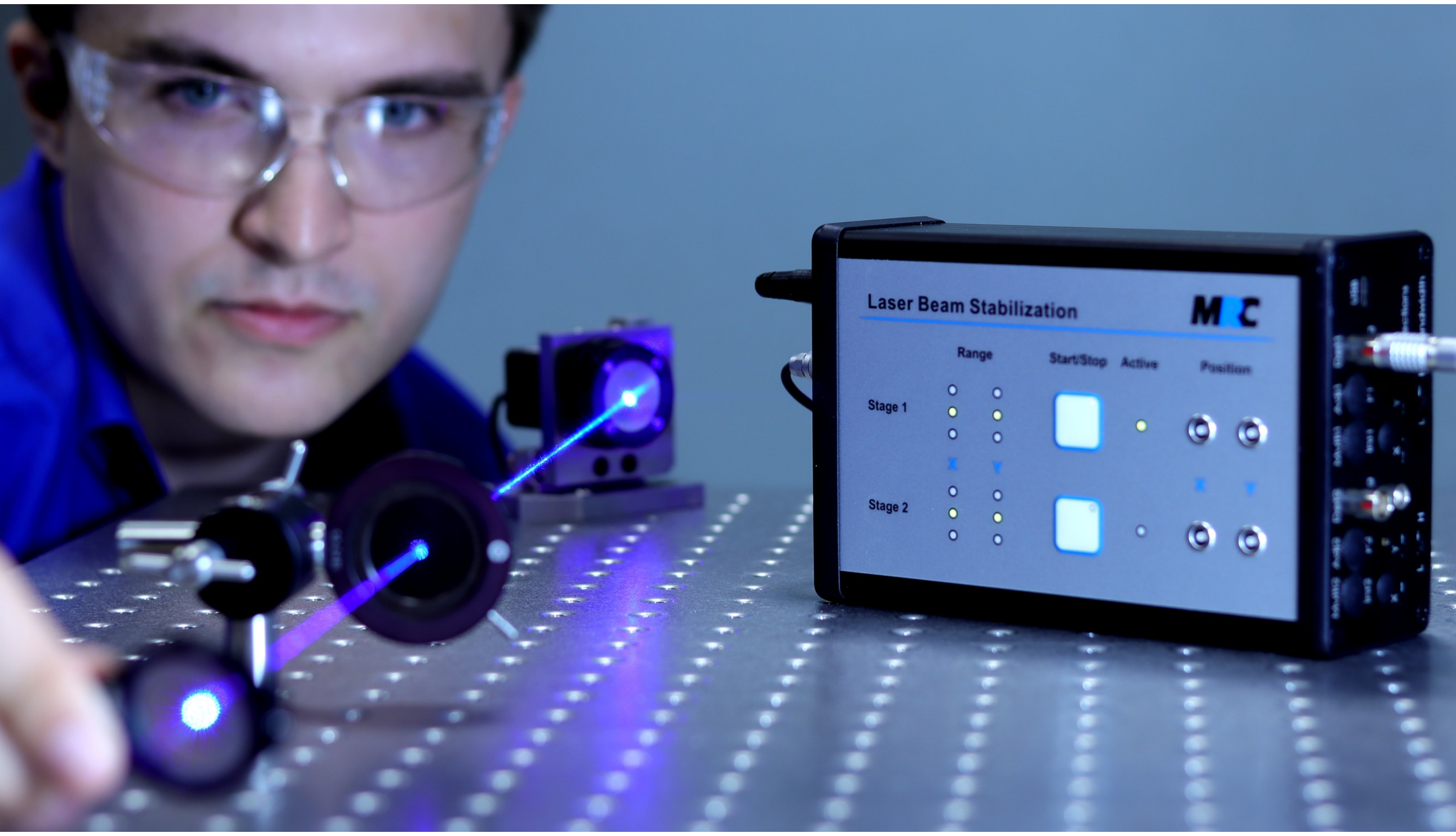

Laser Beam Stabilisation System
Compact

User Manual

Contents

Subject to change without prior notice

1. General

The *Compact* laser beam stabilisation compensates for vibrations, shocks, thermal drift, or other undesired fluctuations of the laser beam pointing. The system should be applied whenever laser fluctuations or movements of optical components occur but a high precision and stability of the beam position and angle is required.

The desired position of the laser beam is defined by a position detector (4-quadrant-diode (4-QD) or PSD). For that purpose a small portion of laser power transmitted through a high-reflective deflection mirror ("leakage") is sufficient.

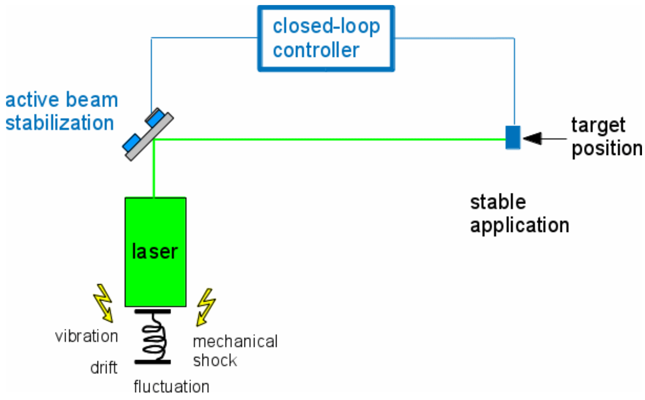

Figure 1: Principle of laser beam stabilisation

The closed-loop real-time control continuously determines the deviation of the laser beam from the desired position and drives the fast Piezo actuators in that way that the steering mirrors stabilise the laser beam in the desired position.

The 4-axes system combines two pairs of detectors and steering mirrors in order to stabilise the laser beam in 4 degrees of freedom (4D, position and angle). The 2-axes system uses only one such pair. It stabilises either the beam position at exactly one point or – if e.g. the detector is placed into the focus of a lens – the beam angle.

2. System components

The laser beam stabilisation utilizes the control electronics and the optoelectronic components (steering mirrors, detectors). The following figures show the standard components. Beyond these, we offer various types of steering mirror mounts with Piezo actuators and detectors. For more details please check the specification in sections 3. and 4. .

Figures 2, 3, and 4 (from left to right): Steering mirror with Piezo drive (version P2S30), detector with position and intensity display (horizontal orientation), detector (vertical orientation)

The system electronics (controller, amplifiers, power supplies) is fully integrated into a single compact housing. It is powered by a standard 12 V wall power supply.

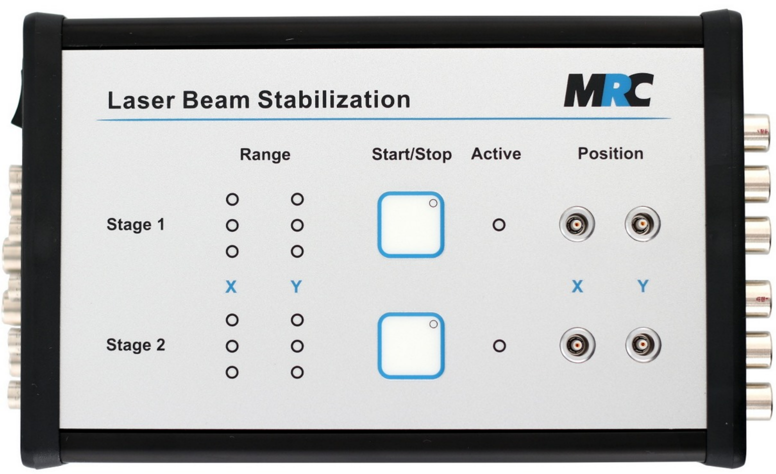

Figure 5: Keyboard and connectors on top panel

Figure 6: Power input and output connectors on left side

Figure 7: Input connectors, P factor adjustment and switches on right side

3. Specification

You can find detailed data sheets of the different components of the beam stabilisation system on our website. We can also send them to you. The following table shows an overview:

Optical parameters	
Wavelength	320 to 1100 nm, UV and IR detectors are also available
Repetition rate	any rate or cw For lasers with low repetition rates (< 1 kHz), with single pulses or with laser off-times we offer an additional sample & hold circuit, see also note 1
Laser beam diameter	< 6-8 mm ($1/e^2$), see also notes (2) and (3)
Height of laser beam	40 mm for *P2S30* and *P4S30*
Mirror diameter	*P2S30:* 1" (standard) *P4S30:* 1", 1.5", 2" and other mirror diameters
Mirror thickness	1/4" or 1/8" (recommended)

Controller housing dimensions	
w x h x d	166 x 106 x 56 mm^3
Control features	
Power level display	LED line with 10 elements on the backside of the detector
Position display	LED cross on the backside of the detector
Variable intensity gain	Continuous, adjustable with digital potentiometer. Adjustment range depends on detector version (vis 4QD: factor 47)
Low power switch-off	Power level falls below 10% of saturation power
Switch on activity delay	Standard: 300 ms, systems with sample&hold (ADDA): 30 ms

Computer interface	
Options	USB, RS-232 or Ethernet

Connectors at controller unit	see also note (4)
Actuator	LEMO 0S series
Detector	LEMO 0B series
Controller status signal (interlock)	LEMO 00 series
x, y position output	LEMO 00 series
P factor setting and read-out	LEMO 00 series
Power supply	12 V / DC pin-and-socket connector

Notes:

(1) A description of the sample & hold circuit is given in section 7 of this user manual.
(2) If the beam diameter is larger than 8 mm, a lens in front of the detector can be used. Please refer to the description “Optimisation of the setup with lenses” on our website for details.
(3) The specification refers to 4-QDs with a sensor size of 10x10 mm². For detectors with smaller sensors, the beam must be correspondingly smaller.
(4) Detailed information on cables and connectors can be found in a separate data sheet.

3.1. Positioning accuracy

The positioning accuracy depends on several parameters:

- Optical distance between steering mirror and detector: The accuracy is higher for larger distances. Therefore a large distance should be chosen.
- Beam diameter: Having the same absolute change of laser beam position, a smaller diameter leads to stronger power differences on the quadrants of a 4-QD and therefore a steeper control signal. That is why laser beams with smaller diameter can be positioned with higher accuracy.
- Intensity: The resolution of the detectors further depends on the intensity hitting the sensitive area. However, this can be varied by optical filters and optimised electronically (see section 5.4).
- Repetition rate and pulse duration: The controller bandwidth can be optimised for different laser parameters. Higher bandwidths lead to a faster reaction and therefore higher accuracy in case of fast fluctuations.

Note: The system uses the centre of the transversal laser beam profile. It does not reduce fluctuations of the laser beam profile itself.

The position signals of the detectors can be read out at the front panel of the controller.

Position outputs x, y	
Description	4 outputs: beam position (stage 1 and stage 2)
Signal	Analog, - 5 V … + 5 V
Connectors	LEMO 00 series

Figure 8 shows the typical resolutions of the 4-quadrant detectors. The example demonstrates that a resolution of better than 100 nm on the detectors can be achieved with an appropriate choice of parameters. The angular resolution can be determined from these data with respect to the respective arm lengths.

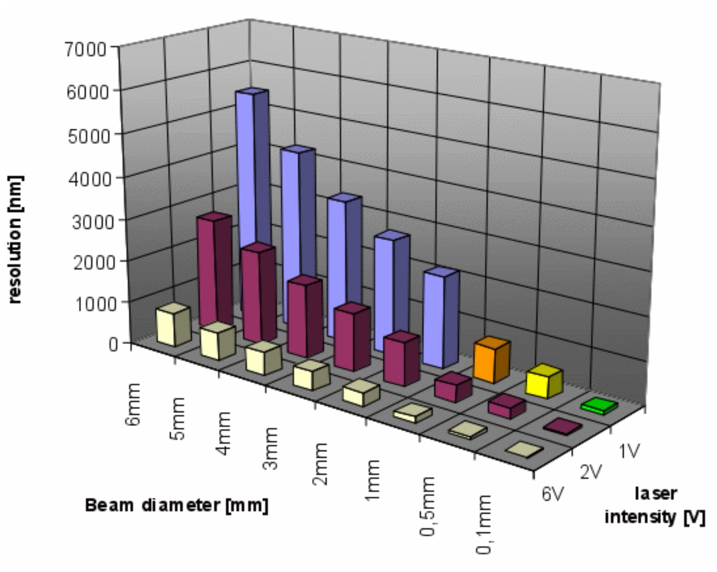

Figure 8: Resolution of a 4-quadrant diode irradiated by a red He-Ne laser with different beam diameters and laser intensities

By the use of the material Invar with a very low coefficient of thermal expansion the detectors are stabilised against temperature variations which ensures that the accuracy is maintained over long term.

The actuators are controlled with an analog signal so that the positioning is not restricted to separate steps. The positioning accuracy of the Piezo elements is in the range of a few nrads.

3.2. Relation between measured voltage and actual position

The position signals are given as voltages. The following formulas allow to convert the voltages into actual positions.

4-quadrant detector

For the calculation, the beam diameter must be determined first. Then the deviations of the positions in µm can be approximated with the following formula which is valid as long as the beam is near to the centre of the 4-quadrant diode:

$$x[\mu m] = \frac{D[\mu m]}{\pi} \cdot \frac{x[V]}{I[V]}$$

where x is the x position signal measured in volts or calculated in µm. The same calculation can be made for y. D is the Gaussian beam diameter ($1/e^2$) and I is the measured intensity signal.

For a more precise calculation or if the beam is further away from the centre, the following formula can be used. Here erfinv() is the inverse error function:

$$x[\mu m] = \frac{D[\mu m]}{2 \cdot \sqrt{2}} \cdot erfinv\left(\frac{x[V]}{I[V]}\right)$$

In case of non-Gaussian beams or to obtain the exact relation, you have to perform a calibration by means of a micrometer stage.

WID-4QD detectors

For detectors with WID (wide intensity) functionality, the formula is simplified due to the constant intensity of I = 6.5 V to

$$x[\mu m] = \frac{D[\mu m]}{6{,}5\,V} \cdot x[V]$$

PSD detectors

In case of PSDs the relation between voltage and position is almost linear. Here you can use the following ratio (similarly for y):

$$x[\mu m] = \frac{x[mV]}{(1.2 \pm 0.03)}$$ for the 9x9 mm² sized PSD for visible light

$$x[\mu m] = \frac{x[mV]}{(2.9 \pm 0.03)}$$ for the 4x4 mm² sized UV PSD

$$x[\mu m] = \frac{x[mV]}{(1.1 \pm 0.03)}$$ for the 10x10 mm² sized UV PSD

You can find further information on the calculations in the description “Position and angular accuracy” on our website.

4. Optical components

In this chapter we summarize some essential properties of the optical components of the beam stabilisation. More detailed information can be found in the respective data sheets.

4.1. Steering mirror mounts

Specification	***P2S30***	***P4S30***
Tilting range	2 mrad (± 1 mrad) mechanical, 4 mrad optical	4 mrad (± 2 mrad) mechanical, 8 mrad optical
Coarse adjustment (manually)	± 4.5°	± 4.5°
Piezo stacks	2 integrated Piezo stacks	4 integrated Piezo stacks
High resonant frequencies	up to 1,200 Hz	> 1,200 Hz (with 1" mirror) ~ 300 Hz (with 2" mirror)
High stabilisation bandwidths	~ 400 Hz (with 1" mirror)	> 400 Hz (with 1" mirror) > 100 Hz (with 2" mirror)
Mirror sizes	1 inch	1, 1.5, 2 and 3 inches
Free aperture for beam transmission	12 x 12 mm²	-

Notes:

- The movable top plate of the Piezo elements is sensitive to mechanical forces. Please avoid the impact of strong forces or torsional moments on it. The Piezo stacks are attached to this plate. If you intend to remove a mirror adapter you should be especially careful.
- For the P4S30 mirror mounts we only include fixation screws for a mirror thickness of 5-6 mm. In case of thinner mirrors you should use shorter screws to avoid a damage of the actuator.

4.2. Detectors

4.2.1. 4-quadrant detectors

Specification	*vis 4-QD (silicon)*	*UV 4-QD 3x3 (enhanced silicon)*	*IR InGaAs 4-QD*	*IR Germanium 4-QD*
Wavelength range	320 – 1.100 nm	190 - 1.000 nm	900 - 1.700 nm	800 - 2.000 nm
Sensitivity range	10 x 10 mm^2	3 x 3 mm^2	Ø = 3 mm	5 x 5 mm^2
Element gap	30 µm	100 µm	45 µm	35 µm

Sensitivity range	depending on detector version e.g. for vis 4-QD: 5–1130 µW / 2-370 nJ @ 532 nm cw (without optical filters, adjustable with gain potentiometer, higher with filters)
Damage threshold	limited by optical filters - typical values: Max. absorbed power: 0.05 – 0.1 W for Ø=1mm, 0.2 – 0.4 W for Ø=3mm Max. absorbed energy: 1-5 µJ for Ø=1mm, 5-20 µJ for Ø=3mm

Dimensions	
Housing (w x h x d)	40 x 49.5 x 23.9 mm^3
Optical filter	11.9 x 11.9 mm^2

Further functions	
Power indication	LED line with 10 elements on the backside
Position display	LED cross on the backside

Connectors	
x, y, intensity outputs	MCX
Power supply	12 V / MCX

4.2.2. Wide intensity detector - 4-quadrant diode with wide intensity range

Specification	
Dynamics / Intensity range	3 decades
Bandwidth	< 10 kHz
Signal scaling	6.5 mV / µm (typical for 1 mm beam diameter)
Sensitivity range	~ 5 µW – 5 mW (@ 532 nm, cw)
Reproducibility over the complete intensity range	10 mV (with 1 mm beam diameter ~ ± 1 µm)

All other specifications are the same as those of the standard 4-quadrant detectors.

The following table shows the relationship between the output voltage of the WID intensity signal, the number of LEDs lit on the housing, and the relative light output on the sensor:

Intensity [V]	Number of LEDs	Laser power [a.u.]
4.0	Saturation limit	3
3.5	Maximum, nominal	1
3.39	10	0.77625
2.44	9	0.08710
1.76	8	0.01820
1.29	7	0.00616
0.98	6	0.00302
0.75	5	0.00178
0.59	4	0.00123
0.49	3	0.00098
0.39	2	0.00078
0.33	1	0.00068

Notes:

- For the wide intensity detector, the function of the intensity display is unchanged. It can still support the selection of the filters. The potentiometer described in section 5.4, however, is omitted.
- Due to the wide intensity range it is possible to detect even lowest laser powers. That is why, depending on the selection of the optical filters, the detection can be affected by ambient light.

4.2.3. PSD detectors

Specification	***VIS PSD***	***UV PSD 4x4***	***UV PSD 10x10***
Wavelength range	320 - 1,100 nm	195 - 1,000 nm	195 - 1,000 nm
Sensitive area	9 x 9 mm^2	4 x 4 mm^2	10 x 10 mm^2

In contrast to the 4-quadrant diodes the PSDs have a continuous measurement area.

Notes:

- If we equip the beam stabilisation with PSDs but no further measures, we use the electronic centre (defined by a voltage of 0V for x and y position) as the target position.
- The position vs. voltage characteristics of a PSD is usually not exactly linear. This means that a pincushion distortion occurs when the beam is sweeping the complete sensor area. I.e. the expected position value can deviate minimally from the voltage value. Therefore, we recommend performing a calibration if the target shall be moved along a defined path.The absolute accuracy at a stabilized position is not affected.

4.3. Vacuum adaptions

Both, the detectors and the actuators, can be adapted for use in vacuum. In case of the actuators, this is possible for vacuum pressures down to 10^{-11} mbar. But this is an extreme value. In case you intend to place some components in vacuum please let us know the conditions so that we can discuss and suggest the required measures. Some measures (choice of materials, cables, sealing) are mainly focussed to avoid degassing and depend on the pressure. Others are important to protect the components themselves.

Notes:

- The controller itself should not be placed in vacuum.
- The vacuum compatible detector does not have the LED displays on the backside. That is why the sensitity can be set remotely (see section 9.2). Furthermore, additional intensity outputs can be integrated into the control box.

4.4. Optical filters

We usually integrate a pair of optical filters in front of each sensor. They have a size of 11.9 x 11.9 mm^2 and fit into the provided slot in the detector housing. The filter which is further inside is usually optically denser.

5. Installation and operation

A quick installation guide is part of the scope of delivery. It explains how to start up the beam stabilisation. If you no longer have this guide, you can download it from our website or ask us to send it. In the following sections, we explain individual steps in more detail.

The system operation can be described best with reference to figures 5 to 7. The top panel in figure 5 shows the keyboard and the position signal outputs for two pairs of detectors and actuators (*stage 1* and *stage 2*). Each stage can be started and stopped independently by pressing the *Start/Stop* button. When the stage is started the small LED in the top right corner of the button is shining. The *Range* display shows whether or not the steering mirrors are within the available capture range. The *Active* LED is shining whenever the control stage is active. This is the case whenever the *Start/Stop* button has been pressed and the laser power on the detectors has the right level.

The *Position* outputs on the top panel can be used to read out the current position of the laser beam on each detector (x and y).

Notes:

- Whenever the *Start/Stop* button is pressed (and the *Active* LED is on) the actuators start to move from the zero position and then respond to the controller input.
- If a *Range* LED is shining red, this does not automatically mean that the beam is not stable. But it indicates that no further tilt of the respective steering mirror is possible if this may become necessary.
- If the power on the detectors is too low the actuators are driven to the zero position (and the *Active* LED is off). This is due to the low power switch off that was implemented for safety reasons (see section 6.2).

Figures 6 and 7 show both sides of the control box with the connectors, the *P factor* adjustment and the switches for the *Directions* and the *Bandwidth* selection. The cables to the actuators are connected on the left side. The cables coming from the detectors are connected on the right side.

The description of the adjustment and read-out of the *P factor* is given in section 5.8. The *Directions* switches enable a coding of the x and y directions of each control stage. They are connected with *Det1* and *Det2*, respectively. The performance is further described in section 5.6. The function of the bandwidth limitation switch is explained in section 6.5.

The *Status* signal output can be used as an interlock or to drive a shutter (see section 6.4).

Note: The Piezo elements have a large electrical capacity. That is why the cables should not be disconnected as long as the Piezo elements are charged. I.e. you should always switch off the power of the stabilisation system on the left side of the panel and then wait for a few seconds before you disconnect the actuator cables.

5.1. Set-up of optical components

The steering mirrors and detectors can be set up in variable arrangements for different applications.

The detectors can be placed behind high-reflection mirrors. They are very sensitive and can work with the leakage behind the mirrors. This has the advantage, that no additional components are required in the beam path. Alternatively, it is possible to use the reflection of a glass plate or a beam splitter. The latter can be necessary for lasers with larger beam sizes where the actuator would constrain the transmission.

In any case, the centres of the detectors should be positioned in that way, that they define the desired laser beam direction. The target positions on the PSD detectors can be different from their centres. For further information please refer to section 4.2.3. The first actuator should be placed close to the laser or the last source of interference. The last detector should be placed close to the target.

Note: Take care for a robust mechanical mounting of the optical components. If possible, the delivered components should be directly tightened to an optical table without further positioning equipment (like height adjustment). If there are oscillating components with resonance frequencies within the control bandwidth in the set-up, such resonances can provoke oscillations of the system at those frequencies.

The following figures 9-13 show a selection of possible arrangements. These examples are demonstrated with the 4-axes system with two detectors. However, they can be applied in similar configurations for the 2-axes system with only one actuator and one detector.

- Figure 9 shows a typical 4-axes set-up of the system where the laser beam hits the optical components in the following sequence: steering mirror, combination of steering mirror and detector, mirror with detector.

- Figure 10 shows a similar set-up where additional lenses are placed in front of the detectors. Further, a beam splitter is integrated in the beam path. This set-up might be better for lasers with large beam diameters. Detector 1 must not be placed in the focal plane, as it can only detect angular errors there, not positional errors (see also the detailed description "Optimization of the setup with lenses").

- In figure 11 a lens is placed in front of detector 2 in order to improve the angular resolution. In this case, the distance between lens and detector should be the focal length of the lens. The focal length itself should be chosen in that way – depending on the beam diameter – that the focal spot is not too small. In case of 4-QDs the beam should still have a diameter on the sensor area of >> 50 µm, so that it hits all quadrants of the diode. (The gap between the quadrants is 30 µm for our standard 4-QD, and even more for other 4QDs.)

- Figure 12 shows a variation of 11 where both detectors are placed behind the same mirror. In order to measure both, the beam position and the direction at the same point, a lens is placed in front of detector 2.

- Figure 13 finally shows an arrangement where the 4-axes system is used as two 2-axes systems, i.e. the two stages of the controller are used to separately stabilise two independent beam lines.

Notes:

- In some cases in set-ups where the distance between the actuators 1 and 2 is rather small, a positioning error can occur. This is the case if detector 1 is not placed sufficiently close behind actuator 2. A lens in front of detector 1 can eliminate this positioning error. The lens and the distances should be chosen in a way that the front surface of the mirror is imaged on the detector. The distances and the focal length f of the lens can be calculated with the lens equation $1/f = 1/b + 1/g$. While g is the distance between the mirror's surface and the lens, b is the distance between the lens and the detector's surface.
- For setups with lenses, please also refer to the description "Optimisation of the setup with lenses" on our website.

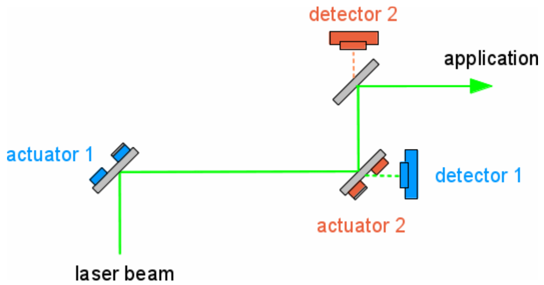

Figure 9: Typical sequence of components for the 4-axes stabilisation: Detector 1 stabilises the beam position on actuator 2. Detector 2 then defines the beam position at a separate point and hence the direction.

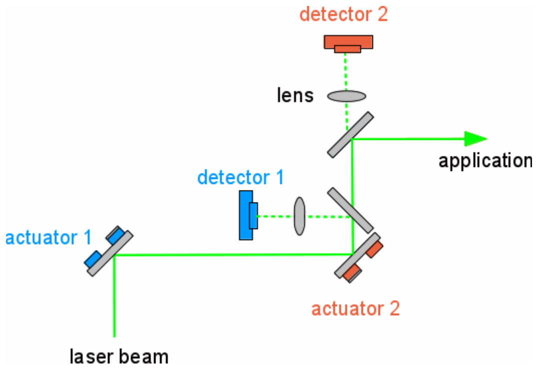

Figure 10: Set-up as in 9, with an additional beam splitter and a lens in front of detector 1 and an additional lens in front of detector 2 (Often used for lasers with larger beam diameters)

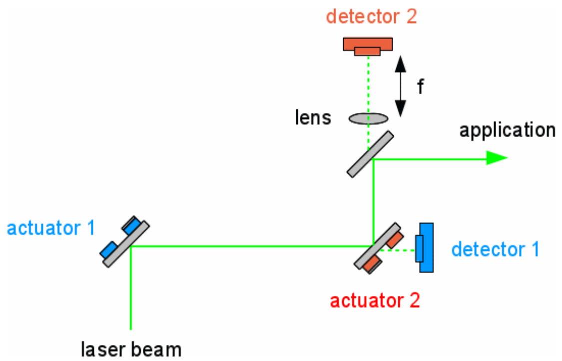

Figure 11: Set-up as in 9, but a lens is used to discriminate the angle by means of detector 2. This can be of advantage in case of restricted space with small distances between the optical components. Detector 2 must be placed in the focal plane of the lens.

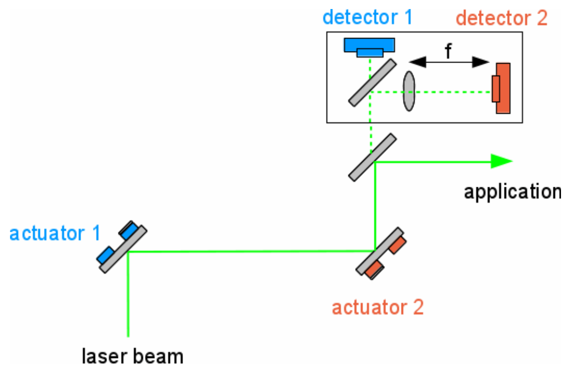

Figure 12: This set-up shows a variation of figure 11. Both detectors are placed behind the same mirror in order to measure both, the beam position and the direction at the same point. A lens is placed in front of detector 2 which discriminates for the angle.

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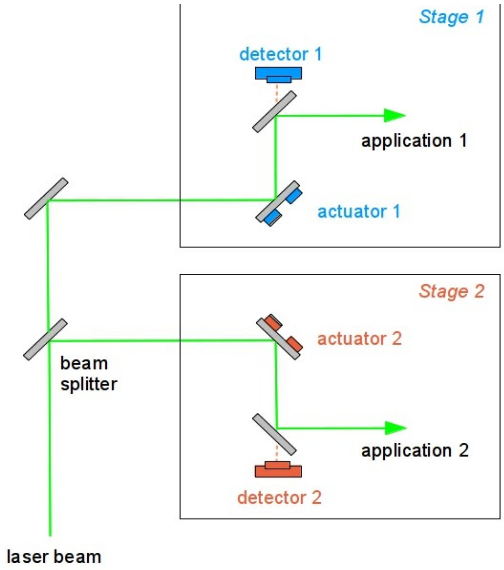


Figure 13: Set-up of a 4-axes system used as two 2-axes systems. With this set-up the position of two independent lasers can be stabilised with one controller.

5.2. Connecting the cables

The first steering mirror is connected to the *Actuator 1* output. The second steering mirror is connected to *Actuator 2*.

The detectors are connected to the control box with a LEMO cable with a length of 4 m and an adapter cable that splits the LEMO cable into four separate cables. These cables are connected to the detectors according to the following rules: The x and y lines have to be connected in accordance to the orientation of the detector housing. If the detector is oriented in vertical orientation as shown in figure 4, the x line has to be connected to the x output and the y line to the y output. If the detector is turned by 90° to a horizontal orientation as shown in figure 3, the x line has to be connected to the y output and the y line to the x output. At the other end, the LEMO cables of the detectors are connected to the respective detector inputs at the controller module.

Note: In case of the 2-axes system you can either use the first or the second stage for stabilisation.

5.3. Power supply

The power supply is provided by the delivered plug-in power supply. The system is switched on via the switch on the left side of the housing.

Note: The power supply is specified with 12V and 3.8A. The 3.8A is not needed during the operation. However, due to the loading of the buffer capacitors and the ramp-up of the high voltage module, the peak currents are quite high when the system is switched on. If at least 3A are not available during the switch-on phase, the high-voltage modules do not reach their rated voltage and there is a risk of damage.

5.4. Intensity adjustment

5.4.1. Adjustment of sensitivity with 4-QDs

The detectors are equipped with LED indicators on the rear side for monitoring of the beam position and the intensity. To make sure that the detectors operate in the linear range, the power level can be adjusted by tuning the potentiometer for intensity variation. For that purpose, switch on the system (Power on) and inactivate the closed-loop control (*Start*/*Stop* button switched off, green *Active*-LED and LED on button off). Then adjust the laser beam onto the detectors in that way that at least 3 but not more than 9 elements of the power level display are shining. If the intensity on a detector is too high the sensor gets saturated. In this case all LEDs of the power level display are blinking.

Most detectors have a digital potentiometer with two small push buttons behind two holes on the side of the housing (see figure 14).

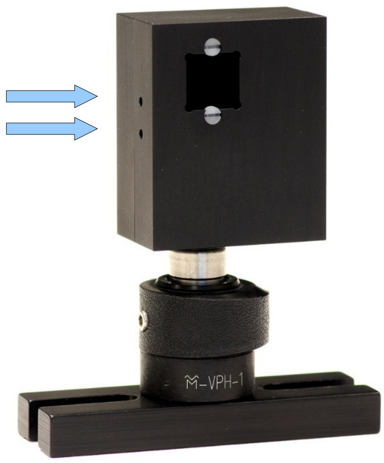


Figure 14: 4-quadrant-diode. The arrows point to the push-buttons of the digital potentiometers for the gain adjustment (which can be carried out with the delivered metal pin)

Pressing the upper button slightly increases the gain. Pressing the lower button reduces it accordingly. A suitable pin is included in the scope of delivery. There are 64 or 128 steps between the highest and lowest gain, depending on the type. For the vis-4QDs, for example, this corresponds to a sensitivity change by a factor of 47. With some detectors, you can continuously adjust the gain by remaining on the respective button.

(Some detectors, especially older ones, have a rotary potentiometer. Here, you increase the gain by turning it counterclockwise.)

If you do not find an appropriate adjustment you have to exchange the optical filters in front of the sensors (see section 5.4.2). If the required filters are not available please contact us.

Notes:

- In a standard delivery we usually integrate two optical filters in front of the sensor. These are filters with a high and a low density for coarse and fine adjustment, respectively. Usually the filter on tip which is the first to be reached is the low density one.
- Please be aware that the sensor is quite sensitive. If you want to clean it you should do this carefully with a lint-free cloth.
- There are also detectors with the option of remotely setting the sensitivity (see section 9.2).

5.4.2. How to replace the optical filters in the detector housing

In some cases it can be necessary to exchange the optical filters. The filters are fixed to the housing with two plastic screws. To replace the filters carefully remove the plastic screws. You can use forceps to hold the screws during the fixation. Usually, the filter with the higher optical density is the one which is deeper in the slot.

5.5. Pre-alignment

For pre-alignment of the laser onto the detectors you should at first not activate the control (*Active*-LEDs off). However, the electronics must be switched on (supplied with power) so that the Piezo actuators drive into their zero positions. The laser should be aligned onto the detectors so that only the green LEDs in the centre of the LED position display are shining. If you use the software, you can also observe the positions there.

5.6. Direction coding of detector outputs

Each control stage makes use of a steering mirror and a detector as described in sections 5.1. For any deviation of the laser beam position on a detector the respective steering mirror is tilted in that way that it aligns the laser beam back to the desired position. The components that are working together are identically coloured in figures 9-13. The direction in which the steering mirror must be tilted depends on the arrangement of detector and steering mirror. It can be changed during the adjustment process described in section 5.7 in the following way:

There are four switches on the right side of the controller module (see figure 7). These switches stand for the x and y directions of the control stages *Stage 1* and *Stage 2*. To turn them into the correct position just activate the respective stage. If the laser beam is then deflected into an extreme x (horizontal) and/or y (vertical) position instead of the centre of the detector, you have to toggle the belonging switch.

5.7. Fine-adjustment

The fine-adjustment should also be performed with inactivated control stages. The better the correlation of desired position and zero position of the Piezo actuators, the smaller the position shift once the closed-loop control is started.

Adjust the laser beam by means of manually tilting the steering mirrors or any other mirrors in the setup in that way, that it hits the centres of the detectors. This can be done by observing the displays in the software or by reading out the x and y position outputs of the controller which deliver voltages that directly depend on the deviation from the target position. You can easily display these signals on an oscilloscope.

A helpful indication for a good adjustment are also the Piezo voltages. If you use the software, you can continue to manually adjust the laser beam onto the detectors with the control-loop activated (*Start* button switched on, green *Active*-LED and LED on button shining) for a final adjustment until all four *Range* displays in the software are close to 5 V. Now the steering mirrors are operating in their linear range.

After these adjustments the system should show no fluctuations of the laser beam position after the last mirror with detector when the controller is activated.

5.8. Adjustment of the proportional element (P factor)

Usually the factory settings of the proportional and integral elements of the control loop lead to a very stable performance of the beam stabilisation system with desired bandwidths. That is why no user interactions are required to adjust the control loop. However, in specific cases the user might wish to adjust the control loop for his application. Such cases can e.g. be setups with rather long arm lengths.

Since the control loop is mainly influenced by the proportional element, the system offers a direct access to the P factors of both control stages by means of potentiometers or via the (optional) computer interface. The potentiometers *P1* and *P2* are located at the side panel of the control box (figure 7). The adjustment can be done separately for each stage. An increase of the P factor usually leads to an increase of the overall bandwidth. In order to optimize the performance, we recommend to start with a small P factor and operate the system in this stable configuration. Then you can increase the P factor by simply turning the potentiometer in clockwise direction or by increasing the values in the software, until the system reaches its stabilisation limits and starts to oscillate. The potentiometers or values should then be turned back to a level, where an operation without oscillations is guaranteed.

Notes:

- The optimal P factors of stages 1 and 2 can differ.
- If the distances of the optical components, the beam diameter, the laser intensity, or other laser data change, the P factor of the overall system might also change.

The system is also equipped with analog inputs for a remote setting of the P factors. The remote adjustment connectors are integrated into the control box in addition to the potentiometers. They are labelled with *P1-Sig* and *P2-Sig* (figure 7). Whenever a voltage signal is applied to the remote adjustment, the potentiometers are ineffective. The input voltages can be set between 0 and 5 V. The interface can also be used to read out the current voltages as set by the potentiometers or in the software.

Specification	
Input/output voltage range	0 … +5 V
Connector	LEMO 00 series
Cable (optional)	LEMO 00 → BNC for each stage, length 2 m, 2 units

Note: The remote adjustment has to be driven with a low impedance voltage source (≤ 1 kOhm), whereas the read-out drives only high impedance terminations (≥ 1 MOhm).

6. Operation and safety features

6.1. Power level and position display

The total power on each connected detector is displayed by means of a LED line on the backside of the detector housing. Furthermore, a LED cross on the detector housing displays the current laser beam position. If the laser beam hits the centre of the detector only the green LED of the position display will shine. In other cases also yellow and red LEDs will shine according to the examples in figure 15.

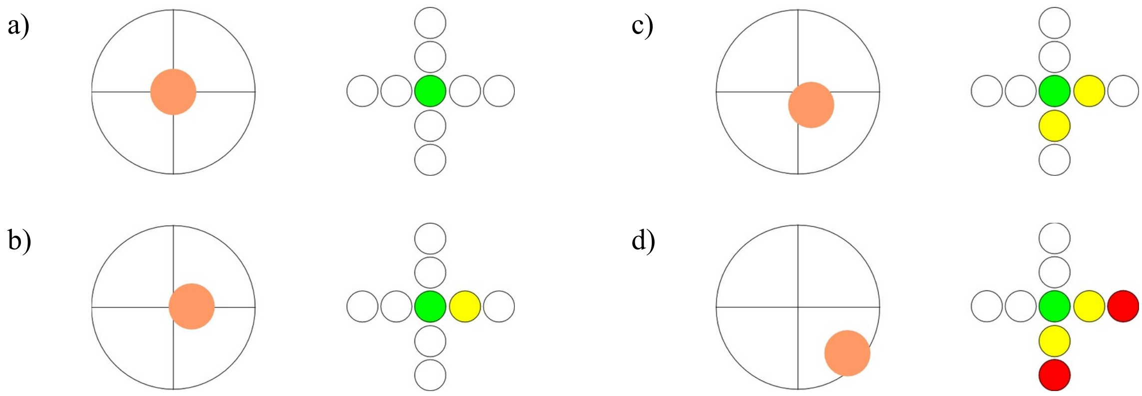


Figure 15: Examples for laser beams hitting the detector (orange spots) and the corresponding position display. The left pictures are shown in a view from the rear side of the housing to the sensor area.

If only green and yellow LEDs are shining the sensor electronics is in the linear range where a direct correlation between measured signal and position exists. If a red LED is shining too, the correlation is no more possible due to the principle of 4-QDs. In case of the PSDs, if a red LED is shining, the beam probably hits an edge of the sensor. Please check if the full diameter of the beam hits the sensor area.

6.2. Low power switch-off

If the total power falls below 10% of the saturation power (only a maximum of two LEDs of the LED line are lit) the controller automatically drives the mirrors into their zero positions. This leads to the advantage that the closed-loop control can start from the zero position even if the laser was switched off or blocked.

6.3. Switch-on activity delay

The integrated switch-on activity delay starts the control only some time after sufficient intensity hits the detector again. This ensures that the control does not start until a reliable control signal is present and the steering mirrors have reached the zero positions. The *Active* LED will not shine during this delay.

6.4. Controller status signal (interlock)

If the system is completely switched off (power off), the Piezo actuators of the *P2S30* tilt the steering mirror into an extreme position. This is about 1 mrad from the zero position. (The *P4S30* does not show this behaviour due to its design with 4 Piezo stacks.) However, the system is equipped with a TTL output that can be used to block or electronically switch off the laser in order to avoid damage by the misaligned beam. The level is HIGH if the steering mirrors are in the correct range or in zero position. It is LOW if one of the actuators is out of range. (If the controller is not active, the level is always HIGH.)

Note: The criterion for the actuators being "out of range" is that the Piezo voltage reaches 95% of its maximum or minimum value.

Status signal	
Description	1 output for both stages
Signal	TTL, LOW if Piezo is out of range
Connector	LEMO 00
Cable (optional)	LEMO 00 → BNC, length 2 m

6.5. Bandwidth limitation switch

The controller bandwidth directly influences the quality of the stabilisation. The system can be operated with two different controller bandwidths. The default setting is the high bandwidth. However, especially in case of unstable mechanical set-ups or if a mutual interference of the control stages occurs it can be of advantage to choose the low bandwidth. Therefore a bandwidth limitation switch is integrated in the controller module (*Bandwidth*, see figure 7, H = HIGH, L = LOW bandwidth). The bandwidth can be chosen independently for both stages.

6.6. Reset function for firmware

Systems with a computer interface have a reset function for resetting the parameters of the P factors and adjust-in function and for setting the hardware handshake to the factory default settings. This is triggered by pressing both *Start/Stop* buttons simultaneously immediately after switching on the power. The LEDs on the buttons light up initially. After approx. 1-2 seconds, they go out to confirm that the reset has been performed.

The reset has the following effects:

- All inputs previously set via software or the interface are switched to “external.”
- The P factors are set to 0 or the externally set values.
- The Adjust-in values are set to 0 or the externally set values.
- The detector sensitivities (in case of the remote option) are set to 0 or the externally set values.
- The baudrate is reset to the factory setting.
- The hardware handshake is switched on.

7. Option: Sample&hold circuit (“ADDA“)

The additional circuit is used to fix the laser beam in the last position during laser off times. With this add-on, which is integrated into the control box, the positions of the steering mirrors can be fixed for an arbitrarily long time interval without control signal or laser intensity on the detectors. In that way it is possible to start the control-loop after switching on the laser not from the zero position but from that latest stabilised position. You can find the detailed description "Sample&Hold circuit ("ADDA")" on our website which explains the various applications of this add-on.

The name “ADDA” is derived from the functional aspect that the actuators' drive signals are first AD converted and digitally stored before they are subsequently DA converted again and fed to the amplifiers of the mirror actuators.

7.1. Technical specification

Sample & Hold circuit	
Storage principle	Digital storage of position data
Freezing interval	unlimited
Requirement for automatic triggering	Minimal laser on time: > 100 ms
External triggering	
Signal levels	TTL, HIGH for laser on, LOW for laser off
Inputs	1 input for each stage
Connector	2x LEMO 00, separate connectors for stage 1 and stage 2
Cable (optional)	LEMO 00 → BNC for each stage, length 2 m, 2 units
Minimal length of trigger signal "high"	$t_{min} \geq 10$ µs
Trigger start	10 µs before until 50 µs after start of laser pulse
Trigger end	max. 1 ms after laser pulse end
Trigger (digital)	
via serial interface	Commands: "SetTriggerFreeze", "ClearTriggerFreeze"

7.2. Modes of operation

Automatic control of sample & hold elements

The beam stabilisation with additional S&H circuit includes an automatic recognition of laser on and off states. This is done by sampling the intensity on the position detectors. The automatic operation controls the S&H elements in order to store the signals during laser on times and fix the position of the steering mirrors during intervals with no intensity.

For this mode of operation the laser on intervals or the respective duration of pulse packages must be longer than 100 ms. In case of the automatic control you do not need to provide any trigger signals.

Note: When using WID detectors (see section 4.2.2), the automatic control does on principle not work.

External triggering of the sample & hold elements

For single laser pulses or lasers with very low repetition rates, modulated cw lasers or pulse trains < 100 ms the automatic control can not release the stored beam position in due time. In such cases it is necessary to control the S&H elements by means of external triggering. The requirements for the trigger signals are described in section 7.3.

7.3. Configuration and start of operation

Cabling

In the operation mode of automatic control there is no need for additional cabling. For external triggering the trigger signals have to be fed into the control box via the respective LEMO connectors marked with "Trig" (see figure 16). The left connector controls the S&H function for stage 1 / steering mirror 1. The right connector controls it for stage 2 / steering mirror 2.

Figure 16: Left panel of control box with trigger inputs

External triggering

The external triggering enables an accurate timely assignment when the system shall store the position of the steering mirrors and when the position shall be fixed. This assignment is especially important in case of single laser pulses. For an optimal function of the S&H circuit there are time restrictions for the trigger signal which should be met. You can find a specification on this in the introductory table to section 7. Figure 17 illustrates the respective tolerances of the trigger signal.

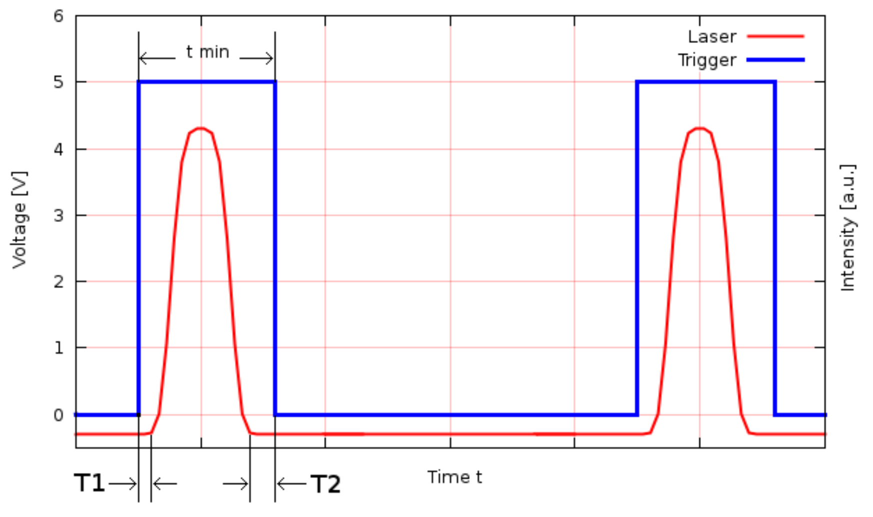


Figure 17: Timing of trigger signal

Start of operation

Whenever the stabilisation is de-activated (i.e. the *Start/Stop* button is in off-state) the stored position of the steering mirrors is reset. In this state the steering mirrors are in their zero position. In this way it is guaranteed that the system can be adjusted as described in this user manual.

Note: Please note that the last position of the steering mirrors is lost whenever the stabilisation is de-activated. As soon as the system is started again it starts from the zero position of the steering mirrors. In case of large distances between steering mirrors and detectors there is a risk that the beam will not hit the detector without a prior re-adjustment.

7.4. Performance

The performance of the additional S&H circuit shall be explained in the following sections with the help of some examples. In figure 18 a sequence of pulse trains with a repetition rate of 1 kHz and a duration of about 300 ms was applied. The pulse trains are displayed with green colour. The violet curve shows the position signal of the laser on the detector.

During the first pulse train the stabilisation was de-activated. You can see that the pulse does not hit the detector in the centre. During the second pulse train the stabilisation was started. You can see an initial spike of the position (enlarged view is shown in figure 19) and then a stable position signal which is also stable during the third and fourth pulse train. Without the S&H circuit the spiking of the steering mirror would occur again and again in the second and all following pulse trains.

At the time the beam stabilisation is started the steering mirrors are in their zero position. Since this position usually differs from the desired position the system recognises a strong control amplitude immediately after its activation. This leads to the described spike. In normal use cases where the laser provides a continuous control signal this is not a problem since the controller always gets a signal. However, in case of some applications, there are time intervals without a control signal. In these cases the additional S&H circuit becomes effective: After time intervals without laser intensity the stabilised operation is re-activated for the next pulse train without a larger spike. This will be demonstrated in the following sections “Automatic control” and “Operation with external trigger”. Without the S&H circuit it would have started from the upper position and would have produced a spike.

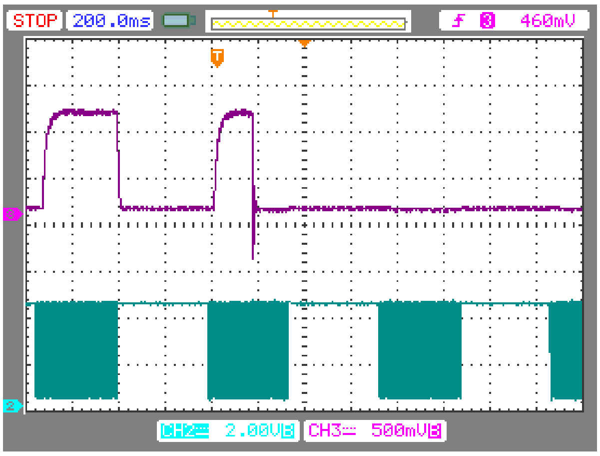


Figure 18: Activation of control-loop

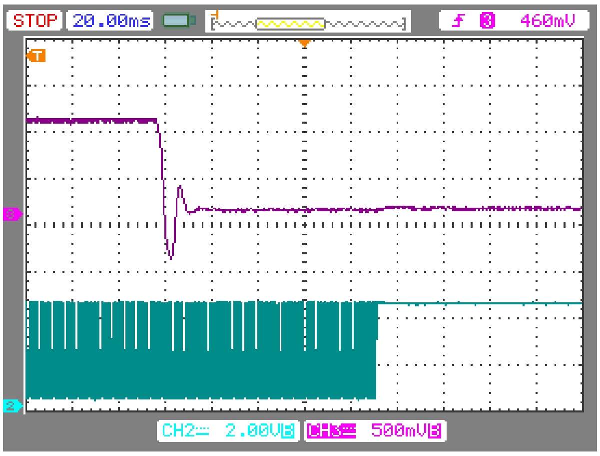


Figure 19: Enlarged view of figure 18

Only for the first pulse train the S&H circuit has no influence since at this time there are no valid position data for the desired position in the S&H elements. After that the control signals for the steering mirrors are stored continuously and for arbitrarily long time intervals where there is no intensity (or for trigger “low” periods). This is true as long as the stabilisation system is switched on and activated.

Note: During the operation, the laser intensity should not be modulated by means of a mechanical laser shutter or other blocking elements. Due to their functional principle, the detectors would determine a wrong position for the short period of the partially covered beam. Therefore the position signal would be distorted.

Automatic control

The operation mode of automatic control is especially suited for long switching periods of the laser light or long trains of single laser pulses.

In figures 20 and 21 an example with pulse trains of a laser with a repetition rate of 1 kHz is illustrated. Again, the green curve shows the laser signal and the violet curve shows the position signals. In figure 20 the laser is running without stabilisation. In figure 21 it is running with the automatic control. In the latter case the position of the steering mirrors is freezed during the laser off times whereby it is refreshed by each signal on the detectors.

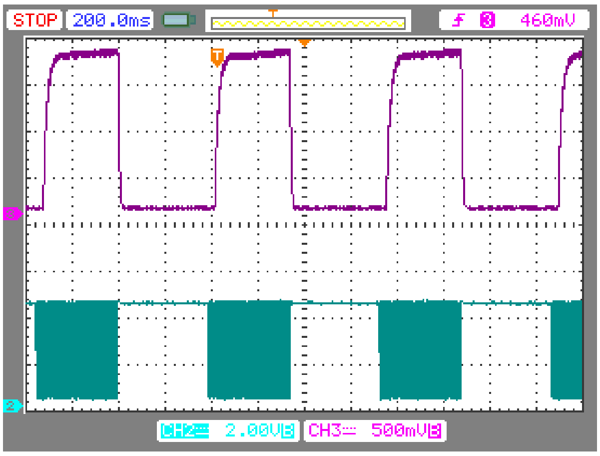


Figure 20: Pulse trains without stabilisation

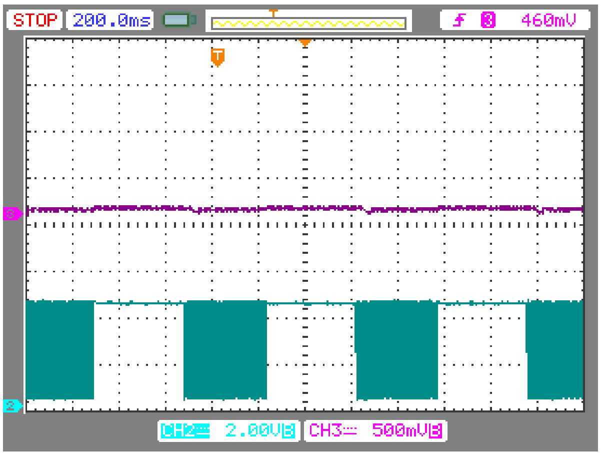


Figure 21: Pulse trains with automatic control

Note: For technical reasons, in the operation mode with automatic control the timing for the position freeze and the re-start of the stabilisation is slightly delayed to the on and off times of the laser intensity. This can lead to slight deviations of the stored positions.

Operation with external triggering

In case a trigger signal for the laser on and off times is available, we recommend to choose the operation mode with external triggering. The improved timely correlation with the laser intensity usually leads to a better performance.

Figure 22 shows the example, now with external triggering. In addition to the curves described above you can see now the trigger signal as a blue curve.

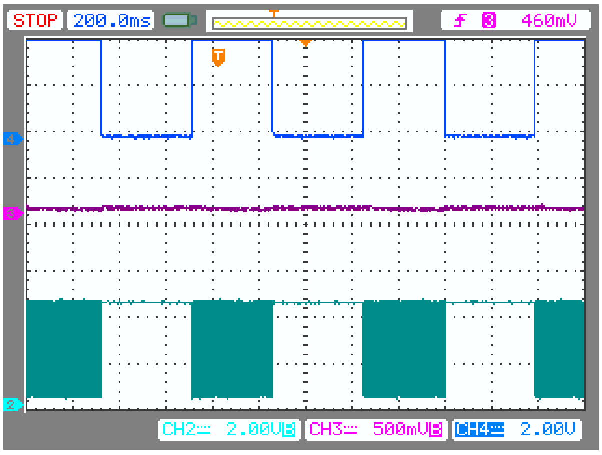


Figure 22: Pulse train stabilised with external trigger

As shown in this example, in case of pulse trains there is an advantage not to trigger on each single pulse but on the start and the end of the pulse train. This is recommended for pulse repetition rates of about 300 Hz and higher.

Operation with single laser pulses and external trigger

The use of an external trigger signal also enables the stabilisation of single or irregularly occurring laser pulses or lasers with very low repetition rates.

The performance in such cases is illustrated with an example in figure 23. Here, the position signal of a laser pulsed at 10 Hz is shown as a violet curve. The green curve shows the trigger signal for single laser pulses. At the beginning, the laser beam is at an arbitrary position. The beam stabilisation is started at the time of the fourth laser pulse (counted from the left). In the following course you can see very well that the beam gets closer to the desired position with each pulse until it finally stays in the desired position in a stable manner.

In this example only four additional pulses are required to reach the stable position. Depending on the set-up of the optical system, the pulse duration and the duration of the external trigger signal the number of required pulses can be different.

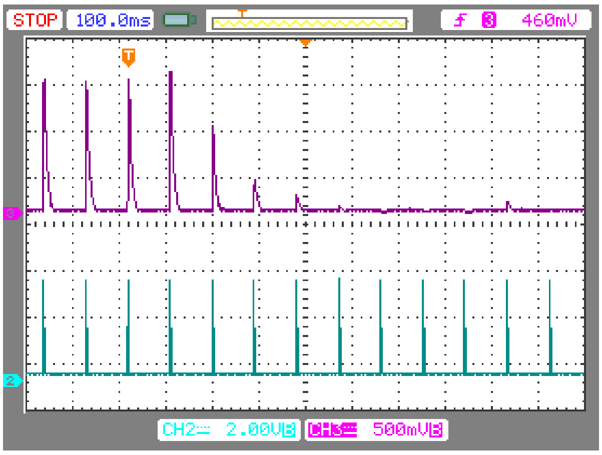


Figure 23: Single laser pulses (10 Hz)

Note: The time interval for the stabilisation is very short in case of short trigger intervals. Since the *Active* LED on the front panel of the beam stabilisation system is directly connected to this time interval, it can happen that you will not recognise the shining of the LED due to the short time.

8. Option: Serial interface (USB, RS-232 or Ethernet)

The optional serial interface allows, amongst others, the following actions:

- the read-out of positions, intensities and Piezo voltages
- the read-out of the status
- switching on and off of the control loop
- the set & hold functionality for current positions. Here, a current position of the laser beam on the detectors is saved and used as the target position for the further stabilisation. This function is especially used in combination with the PSDs as detectors.
- the setting and read-out of parameters as the P factor, the offsets for the Adjust-in target positions

on PSDs, the voltages for the Drive actuator function, etc.
- parameter settings for data streams

Only those functions are available, which are also realized in the hardware, i.e. where e.g. the additional electronic circuits are integrated into the control box.

The option includes a software for visualization and communication. You can find detailed information about the software in the separate software manual on our website. For integration of the system with your own software you can further find the description of the communication protocol there. You can also ask us to provide the documents.

9. Additional inputs and outputs (Options)

Beside the inputs for the detectors and the outputs to the actuators the basic configuration of the *Compact* beam stabilisation provides the following outputs:

- Position signals x and y of each detector (analog voltage signal -5 to +5 V)
- Adjustment and read-out of the proportional element (P factor) (see section 5.8)
- Status signal (see section 6.4)

Other optional signal outputs or inputs are described in the following sections.

Note: In some cases the arrangement of the connectors on the side panels are changed.

9.1. Voltage offset inputs to move the target position on PSDs ("Adjust-in")

As described in section 4.2.3 the measurement principle of PSDs allows to move the target position on the detector by means of a voltage offset. The offset values can be applied via the optional serial interface and the software. You can enter values in the voltage range of -5 V ... +5 V. Alternatively, we can implement additional analog inputs for the x and y axes of both stages, 1 and 2. These inputs can be used to change the still stabilised beam position by an external source. Figure 24 shows the modified side panel of the control box with additional inputs *Adj1* and *Adj2*.

Figure 24: Right panel with additional "Adjust-in" inputs for x and y position of two PSDs

Note: The position vs. voltage characteristics of a PSD is usually not exactly linear. Therefore, a calibration should be performed if the target shall be moved on a desired path.

Specification	
Description	2 analog inputs LEMO 3-pin, one for each detector (x, y) or via serial interface
Signal	- 5 V … + 5 V
Connector, analog	LEMO 0S
Cable, analog	LEMO 3-pin → 2x BNC, for each stage, length 2 m, 2 units

9.2. Remote sensitivity setting of detectors

The beam stabilization detectors can be equipped with remote sensitivity setting on request. This option is integrated as standard in vacuum detectors, as the usual potentiometer for adjustment is generally not accessible in these detectors. In systems with a computer interface, this option allows the sensitivity to be set via the software or corresponding interface commands.

Another option allows the setting of the sensitivty via external analog voltages supplied to a relocated signal processing unit (typically for vacuum detectors) or to an additional input at accordingly modified detectors.

Note: To use the remote sensitivity setting, the controller must have at least firmware version 3.1 installed and the connected computer must have software version 2.3.x installed.

Setting via software / interface

The sensitivity setting can be accessed via the software's *Parameter* window and/or via the "Set Detector Sensitivity" or "Get Detector Sensitivity" commands. If a controller that allows sensitivity adjustment is connected, a line labeled *Sensitivity in [V]* appears in the *Detector* section. Here, a sensitivity can be configured separately for each of the two detectors. To do this, first set the s*oftware / external* switch to *software*. Then a voltage can be entered in the input field. The following applies to this voltage:

- The greater the voltage, the greater the sensitivity of the detector, which produces a higher intensity signal under constant illumination.
- The voltage can be set to values between 0.1 V and 5 V. Values below 0.1 V cannot be registered by the detector, which is why the sensitivity and thus also the intensity signal do not change. For vacuum detectors with an additional signal processing box, the values are between 0.25 and 5 V.
- The intensity measured at a given voltage depends largely on the light power. This means, above all, that the intensity does not necessarily correspond to the set voltage. A voltage of e.g. 5 V does not necessarily produce an intensity of 5 V.
- The sensitivity of the detector is adjusted in steps. Accordingly, a small change in voltage may not cause a change in the registered intensity. The step size is approximately 0.1 V.

After entering a sensitivity voltage, it can be applied by clicking *Apply*. If the newly set sensitivity differs from the previously set sensitivity, this should be visible as a jump in the intensity signal.

If the sensitivity voltage is not changed for more than 10 s,, the detector saves the current sensitivity. If the analog sensitivity is then set to *external* using the *software / external* switch, the sensitivity does not change. The same applies if a sensitivity voltage < 0.1 V is set.

Once the sensitivity is saved as described above, the external voltage can be switched off or disconnected. After restarting the system, the detector automatically resets the last saved sensitivity.

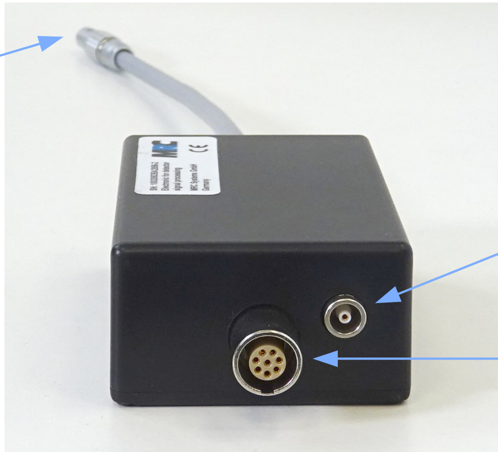
Note: The sensitivity voltage is stored in the non-volatile memory inside the controller. When the controller is switched off and on again, the last stored sensitivity voltage should be automatically restored after approx. 5 s. This also applies if the controller is not connected to the software.

Setting via external voltage

In addition to software adjustment, detectors with external signal processing (see figure 25) also allow the sensitivity of the detector to be changed via an externally supplied voltage. The coaxial socket (Lemo 0S.250) on the signal processing box (*"Electronic for detector signal processing"*) can be used for this purpose.

Voltages between 0.1 V and 5 V are permitted at this input. Voltages < 0.1 V are interpreted as if the plug were not inserted, so that the last stored sensitivity setting is effective.

Important: The voltage at the analog input must not exceed 5 V!



9.3. Direct drive of Piezo actuators („Drive Actuator")

As an option for the direct drive of the Piezo actuators (i.e. without feedback from the detectors) we can implement additional input channels to the controller. It is then possible to drive the actuators with an external voltage signal. This option makes use of the integrated 4-channel high-voltage amplifier of the system. The input signal will be converted to a high-voltage signal which is fed to the Piezos.

Specification	
Inputs	2 inputs LEMO 3-pin, one for each actuator (x, y), - 5 V … + 5 V
Outputs / to Piezo actuators	2 actuator connectors on side panel, LEMO 0S series, 0 V to 130 V
Output impedance	110 Ohm@1 kHz, designed for high capacitive load

Notes:

- The voltage range of the Piezo actuators is specified as - 45 V to + 180 V.
- We have specified the voltages for the valid range of the green *Range* LEDs on the control box to values of 9 V to 120 V (max. range 0 - 130 V).
- There is a non-linearity in both, the characteristics of the Piezos with their hysteresis and the amplifiers. Therefore the signal will not be fully proportional to the input signal. If you need a precise and absolute position of the steering mirrors (without the control-loop which usually gives the position feedback) you should carry out a calibration of the angles versus voltages.
- It is also possible that the x and y axes of the same Piezo actuator vary strongly.

9.4. Option: External activation

The external activation enables the change of the operation state of the beam stabilisation system with an external signal. The external activation can be independently applied for stage 1 and stage 2 of the stabilisation system. For this purpose, two LEMO connector plugs (series 00) are embedded on the left panel of the control box. The inputs are marked as *Ext1* and *Ext2*.

There are three operation states. The specification of the control signal is as follows:

Signal (Level: 5V TTL)	**Voltage range**	**Controller status**	**Reaction of *Start/Stop* LED**
H (high)	2.4 – 5.0 V	Start	on
L (low)	0.0 – 0.8 V	Stop	off
Z (high impedance or not connected)		Manual mode according to selection on front panel	on/off

9.5. Intensity outputs at controller

We can add additional intensity voltage outputs at the control box. These outputs are marked with *Int1* and *Int2* on the side panel of the control box.

Specification	
Description	2 outputs for laser intensities of detector 1 and 2
Signal	Analog, 0 - 8 V
Connector	LEMO 00
Cable (optional)	LEMO 00 → BNC, for each stage, length 2 m, 2 units

9.6. Range outputs for monitoring applied Piezo voltages

In some applications it can be helpful to know the applied voltage ranges of the Piezos, e.g. to see whether or not the tilting range of the Piezos (and therefore the voltage range) is at its limits. If the Piezo actuators are combined with additional motorized mounts in order to enlarge the overall tilting range, the Piezo voltage can be used as a trigger to drive the motors.

Specification	
Description	2 outputs LEMO 3-pin, one for each actuator (x, y)
Signal	Analog, 0-10 V
Connector	LEMO 0S / Labeled with *Multi1* and *Multi2*
Cable	LEMO 3-pin → 2x BNC, for each stage, length 2 m, 2 units

10. Drawings

Drawings of all main components can be found in the respective data sheets. On request, we are pleased to send you the corresponding STEP files.

11. Cables

11.1. Standard cables

The standard delivery of a *Compact* laser beam stabilisation system includes all required cables to set up the system and to read out the positions. These are:

Cable set for a 4-axes system (included in standard delivery)	quantity	length
Detector → Controller	2	4 m (including the 4x MCX → LEMO adapter cable)
Actuator → Controller	2	2 m (directly mounted to Piezo element)
Actuator → Controller (extension)	1	10 m
x, y position cable (LEMO → BNC)	2	2 m

The pin assignments for these cables can be found in a separate data sheet.

11.2. Additional cables

In addition to these cables we can also offer additional cables or cables with other lengths. The following table shows some examples.

Other available cables and/or lengths (examples)	Typical lengths
Extension cables for detectors (LEMO → LEMO)	1 m … 25 m
Extension cables for actuators (LEMO → LEMO)	1 m … 25 m
Cables for external activation (LEMO → BNC)	2 m
Cables for adjust-in, range output, drive actuator (LEMO (3-pin)→ 2x BNC)	2 m
Cable for sample&hold circuit "ADDA" (LEMO → BNC)	2 m
USB cable (USB A → micro USB)	2 m

If you do not find the cable you need please do not hesitate to contact us.

12. Troubleshooting

12.1. No signals on display

Please check if the power line chord is connected to a conducting power plug and if the power switch at the controller unit is activated. If everything is okay with the power line, please contact us or your distributor.

12.2. No signals on detector

Please follow the instructions in section 5.4 and check if an aperture or edge is blocking the laser. If the laser beam hits the sensitive area of the detector another reason can be that the chosen filters are too strong. In that case the filters should be exchanged.

12.3. The laser beam is not correctly positioned

Please check the following issues:

i. Is the laser power in the allowed range?
ii. If red *Range*-LEDs are on:
   a. Are all cables connected as described in section 5.2?
   b. Is the initial position of the laser beam in an acceptable position? If the initial position has changed strongly the closed-loop control does not work in the linear range any more. Please refer then to section 5.7.
   c. Is the direction coding correct?

12.4. The steering mirrors make exceptional noise

Please **immediately** switch off the system. Irreparable damage to the steering mirrors can occur. Then check the laser power on the detectors and adjust it as described in section 5.4. Make sure that the initial laser beam has not changed strongly and that it hits the detectors. Take care that the beam is not blocked by an aperture or an edge anywhere in the beam path. This could be the case at the cut-out of the Piezo actuator. If a red *Range*-LED is on, the closed-loop control does not work in the linear range any more. Please refer to section 5.4 then.

12.5. Laser position is not stable

If the automated stabilisation of the laser beam does not work although the controller is active this might be due to a wrong direction coding of the detector inputs (see section 5.6). Please check the direction coding.

Another reason might be an unstable mechanical set-up leading to oscillations of the system. Usually this phenomenon is accompanied by an exceptional humming noise. E.g. high positions of components (especially of those carrying the Piezo elements) can lead to mechanical instabilities. In this case a better stabilisation can be achieved with a lower controller bandwidth. Please activate the bandwidth limitation switch (see section 6.5).

12.6. Permanently red "Range" signal

A "*Range*" signal that is permanently shining red on the top of the control box may indicate a problem with a high-voltage channel. "Permanently" primarily means that the red LEDs are also shining when the control loop is not activated. This behaviour may be caused by a short circuit in a Piezo element. Usually this has caused the fuse to blow and prevents the further use of the beam stabilisation. Please get in touch with us. We will then clarify in more detail which tests you can perform to determine the cause of the error.

12.7. "Range" signals jump back and forth when switching the direction coding

If a "*Range*" indicator of a control stage jumps from one extreme to the other (from red to red) when the direction coding is switched (see section 5.6), this indicates that the associated detector is rotated by 90°. In this case, swap the cable connections of x and y at the detector as described in section 5.2.

12.8. System steers the beam away from the centre

If the system keeps trying to steer the beam away from the centre of a detector when the control loop is activated, this could be due to a remaining setting of values for *Adjust-in* in the software. In this case, delete the corresponding values or switch to "*external*" in the software.

13. Safety

The system has left our factory in a faultless state. Please store and operate the system in dry environments in order to maintain this state.

The device fulfills the requirements of the European EMC Directive 2014/30/EU.

Labels

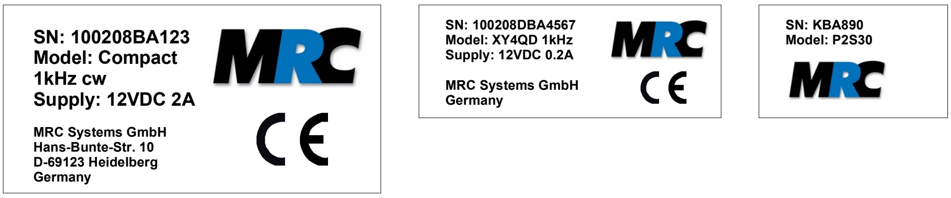


Figure 25: Labels on the controller electronics (left), the detectors (middle) and the actuators (right)

14. Contact

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