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 direction. The system should be applied whenever laser fluctuations or movements of optical components occur but a high precision and stability of the beam direction is required.

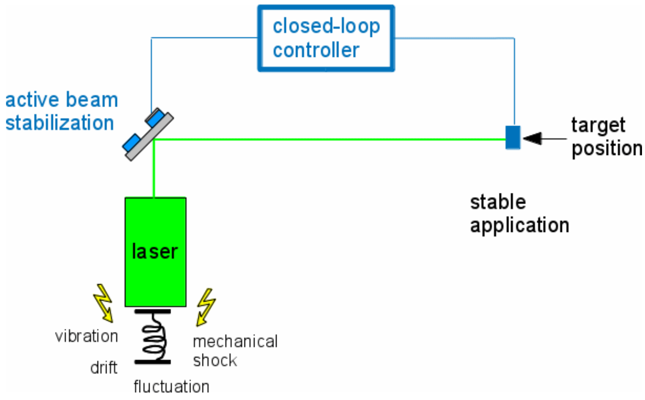


Figure 1: Principle of laser beam stabilisation

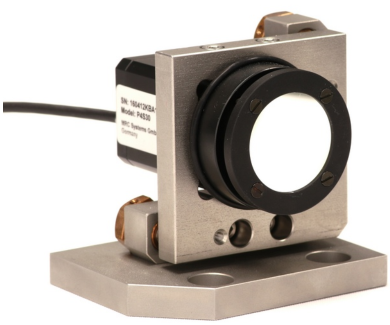
The desired position of the laser beam is defined by a 4-quadrant-diode (4-QD) or a PSD. For that purpose a small portion of laser power transmitted through a high-reflective deflection mirror is sufficient.

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

The system is available in two different models. The 2-axes system comprises one detector and one steering mirror and controls the laser beam in two axes. Thus, the laser beam is fixed in one position but the beam direction can change. The 4-axes system combines two detectors and two steering mirrors in order to detect the laser beam at two distant positions. Thereby both, position and direction are fixed.

2. System components

The laser beam stabilisation utilizes optoelectronic components (steering mirrors, detectors) as well as electronic modules. We offer different types of actuators and detectors. For more details please check the specification in section 3 and the photos in section 4.



Figures 2, 3, and 4 (from left to right): Steering mirror with Piezo drive (version P4S30, 1 inch), 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.

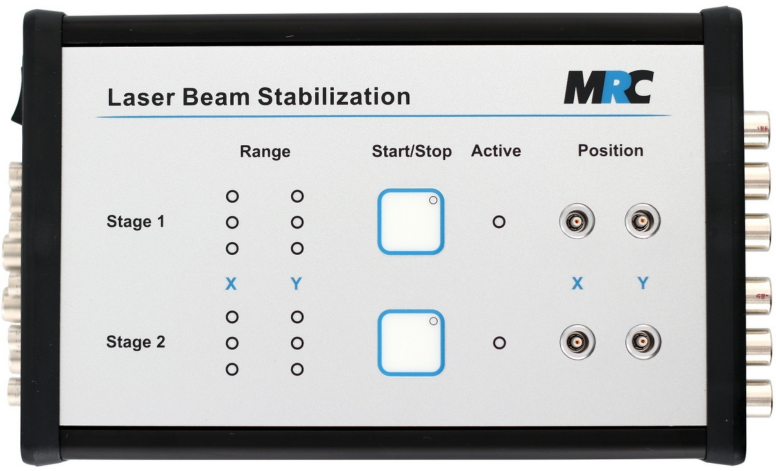


Figure 5: Keyboard and connectors on top panel

Figure 6: Power input and output connectors on left side

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

3. Specification

Optical parameters	
Wavelength	320 to 1,100 nm, UV and IR detectors are also available
Repetition rate	any rate or cw For repetition rates < 300 Hz, operations with single pulses or laser off-times we offer an additional sample & hold circuit, see also note 1
Laser beam diameter	< 6 mm ($1/e^2$), see also note 2
Height of laser beam	45 mm for *PKS*, 39.5 mm for *PSH,* 40 mm for *P4S30* (Please ask for adapters if you need other heights.)
Mirror diameter	1" (standard), 1.5", 2" and other mirror diameters possible
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 potentiometer (1:6)
Low power switch-off	Power level falls below 10% of saturation power
Switch on activity delay	300 ms

Connectors at controller unit	
Actuator	LEMO 0S series
Detector	LEMO 0B series
Controller status signal (interlock)	LEMO 00 series
x, y position output	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) In case the beam diameter is larger than 6-8 mm, a lens in front of the detector can be used. For larger beam diameters adapters for 1.5", 2" or other sizes are available (see also section 4.1.4).

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. The first steering mirror should be placed close to the fluctuation source.
- 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. This can be varied by an appropriate choice of optical filters and optimised electronically (see also section 5.5).
- 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 intensity 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 with the position outputs on 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

In figure 8 the typical resolutions of the 4-quadrant detectors are displayed. The example shows 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.

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.

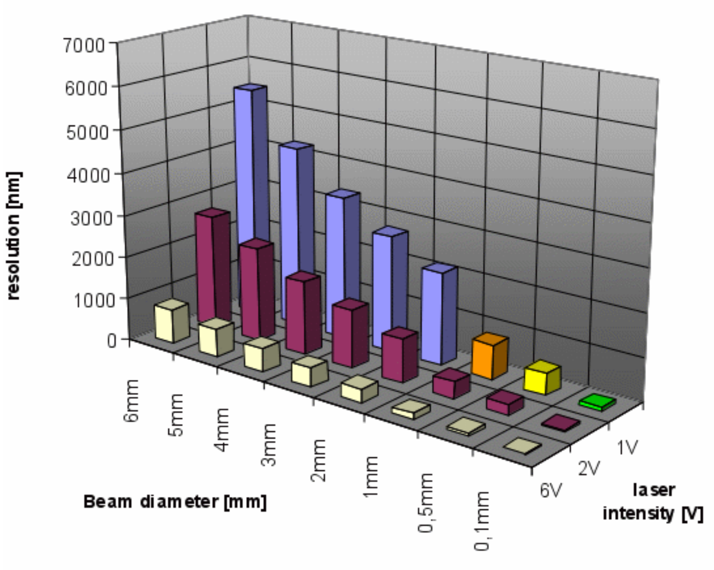


Figure 8: Resolution of a 4-quadrant diode irradiated by a red He-Ne laser with different beam diameters and laser intensities

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 are specified as < 2 nrad (*PKS*) and 4 nrad (*PSH*).

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

The beam diameter must be determined. 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.

PSD detector

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

$$x[\mu m] = \frac{x[mV]}{(1.2 \pm 0.03)}$$

4. Optical components

4.1. Steering mirror mounts

4.1.1. P4S30

The *P4S30* has a comfortable tilting range of ± 2 mrad mechanically, which means ± 4 mrad optically. It is also recommended for larger mirrors (> 1").

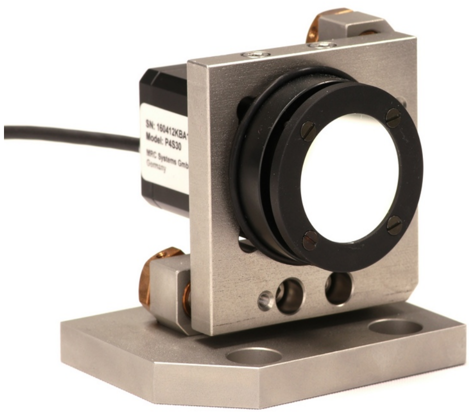


Figure 9: P4S30 with 1.5" adapter on adjustable mount

Figure 10: P4S30 with 4" adapter on stiff mount

Compared to the *PKS* and *PSH* mounts with 2 integrated Piezo stacks, it has 4 Piezo stacks resulting in a higher stiffness and higher resonant frequencies. Thus, the *P4S30* can work with higher stabilisation bandwidths. The P4S30 does not have a free aperture to place a detector behind its mirror.

Specification	*P4S30*
Tilting range	4 mrad (± 2mrad) mechanical, 8 mrad optical
Coarse adjustment (manually)	± 4.5°
Piezo stacks	4 Piezo stacks integrated
High resonant frequencies	> 1,200 Hz (with 1" mirror) ~ 300 Hz (with 2" mirror)
High stabilisation bandwidths	> 400 Hz (with 1" mirror) > 100 Hz (with 2" mirror)

4.1.2. PKS

The mirror mount *PKS* has a tilting range of ± 0.5 mrad which is smaller than the range of the *PSH* and *P4S30* mounts (see sections 4.1.3, 4.1.1). In comparison, it offers a wider free space behind the mirror so that a detector can be placed behind the mirror to detect the leakage. The free aperture is 13 mm. The mount can be adjusted manually for coarse adjustment. Figure 11 shows a photo of this mount.

Specification	*PKS*
Tilting range	1 mrad (± 0.5 mrad) mechanical, 2 mrad optical
Coarse adjustment (manually)	± 2°
Piezo stacks	2 Piezo stacks integrated
Resonant frequency	~ 700 Hz (1" mirror, mirror thickness 1/8")

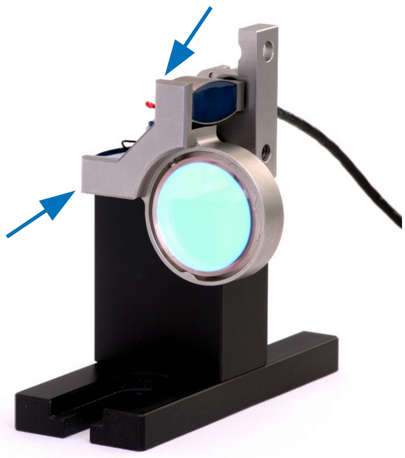


Figure 11: Steering mirror mount PKS with 1" mirror.
The blue arrows point to the x and y labels

4.1.3. PSH

The mirror mount *PSH* has a wider tilting range of ± 1 mrad. It can also be adjusted manually for pre-adjustment to the zero-position.

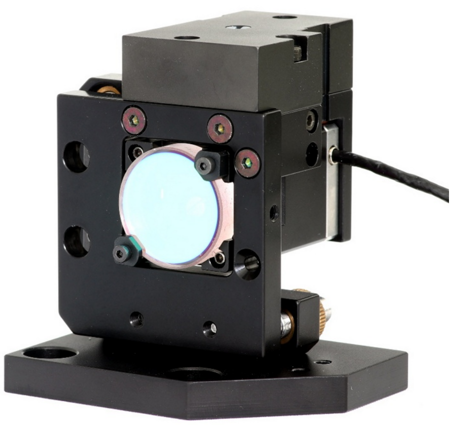


Figure 12: Steering mirror mount PSH with 1" mirror

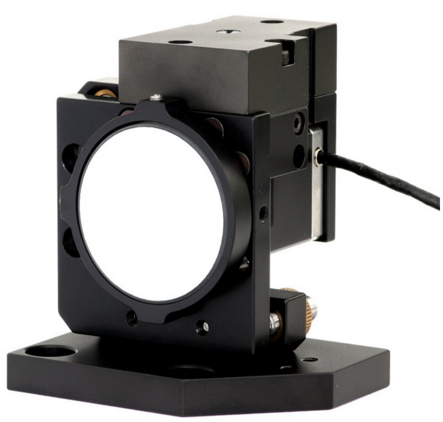


Figure 13: Steering mirror mount PSH with adapter for 1.5" mirror

Specification	*PSH*
Tilting range	2 mrad (± 1 mrad) mechanical, 4 mrad optical
Coarse adjustment (manually)	± 5°
Piezo stacks	2 Piezo stacks integrated
Resonant frequency	~ 840 Hz (1" mirror, mirror thickness 1/8")

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 the 1.5" adapter you should be especially careful. We can provide a specific instruction and a tool for this purpose.

4.1.4. Mirror mounts and adapters for other mirror sizes

Our standard mirror mounts have 1" mirror holders. The *PKS* mount is also available for 0.5" mirrors.

Anyway, our beam stabilisation system can also drive mirrors with larger dimensions. For such mirrors the system is equipped with specific Piezo-driven actuators and mounts, where the design is optimised with respect to control speed and tilting range. For 1.5" mirrors, the *PSH* and *P4S30* steering mirror mounts can be used. Especially for mirrors with diameters of 2" or 3" we recommend the *P4S30* mount. It works with four mutually clamped Piezo stacks and therefore yields a higher dynamic.

Note: With larger mirror masses the bandwidths can be lower than with standard components.

4.2. Detectors

4.2.1. Standard 4-quadrant detector

Figure 14 shows the front side with the detection area of the standard 4-quadrant diode. Figure 15 shows the rear side of the detector with the LED cross and line and the connectors.

Figure 14: Standard detector (4-quadrant diode with sensitive area of 10 x 10 mm^2)

Figure 15: Rear side of the standard detector

Specification	
Detector type	Si 4-quadrant diode
Wavelength range	320 – 1,100 nm
Bandwidth	Up to 100 kHz
Sensitivity range	~ 10 µW - 165 µW @ 520 nm, cw (using the intensity potentiometer)
Detection area	10 x 10 mm²

Dimensions	
Housing (w x h x d)	40 x 49 x 23.9 mm³
Optical filter	11.9 x 11.9 mm²

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

In some applications the laser intensity is varied or modulated over wide ranges. The performance of the wide intensity detector is fully independent of the intensity. The signal amplification automatically adapts to the changing intensity. The intensity can vary by a factor of >1,000 without the need of exchanging the optical filters. External signals or user interactions are not required. The signal-to-noise ratio is not significantly changed over the entire intensity range, so that the stabilisation system reaches the maximum resolution. The function of the power level display is unchanged compared to the standard 4-quadrant detector. I.e. it can still be used to support the selection of the optical filters. In contrast, the potentiometer as described in section 5.5 is omitted.

Advantages:

- dynamic range / intensity range: 3 decades
- less noise compared to standard 4-QDs

Specification	
Bandwidth	< 10 kHz
Signal scaling	9 mV / µm (typical for 1 mm beam diameter)
Sensitivity range	~ 5 µW – 5 mW (@ 520 nm, cw)
Reproducibility over the complete intensity range	10 mV (with 1 mm beam diameter ~ ± 1 µm)

All other specifications are the same as for the standard 4-quadrant detector.

Note: Due to the wide intensity range it is possible to detect even lowest laser powers. Therefore, depending on the selection of the optical filters, the detection signal can be affected by ambient light.

4.2.3. 4-quadrant diodes for UV and IR

For lasers with UV and IR wavelengths we offer 4-quadrant-diodes with different sensitive areas and the following specs:

Specification	UV 4-QD 3x3	IR 4-QD InGaAs	IR 4-QD Germanium
Wavelength range	190 - 1,000 nm	900 - 1,700 nm	800 - 2,000 nm
Sensitive area	3 x 3 mm²	Ø = 3 mm	5 x 5 mm²

Figure 16 shows a photo of the sensor side of the UV 4-quadrant diode 3x3.

Figure 16: UV 4-quadrant diode with sensitive area of 3x3 mm²

4.2.4. PSD detector

As an alternative to our 4-quadrant diodes we offer a PSD (position sensitive device) with the following specs:

Specification	VIS PSD
Wavelength range	320 - 1,100 nm
Sensitive area	9 x 9 mm^2

In contrast to the 4-quadrant diode the PSD has a continuous measurement area. This leads to two possible advantages:

1) The sensitive area is not divided by a gap. Therefore, the PSD can be used in case of very small beam diameters or focused beams (depending on the resulting power density, especially for pulsed lasers).
2) Whereas with the 4-quadrant diodes the target point is usually defined by their centre, in case of the PSDs any other point on the sensitive area can be chosen as a target point.

Applications

If you use the PSDs instead of 4-quadrant diodes, the position detection is not limited to the centre as it is with 4-quadrant diodes. By adding a voltage to the signal of the PSD the target position where the laser beam shall hit the PSD can be moved. Still, the beam stabilisation will provide full stabilisation of the beam position, but the position itself can be manipulated. The external signal can be applied to the system via the “Adjust-in” functionality described in section 10.2.

This feature can be used for different applications, e.g.:

- Place the PSDs before the laser is finally adjusted. Then adjust the laser and read out the target position. Feed back the voltage for the new target position. The system will then stabilise the laser beam onto this position.
- Place the PSDs before the laser is finally adjusted. Then move the position on the detectors by changing the offset voltage until you have the optimal laser adjustment.
- Move the laser beam to different points (or along a pattern) by moving the set point for the beam

position on the PSDs. You can vary the laser beam direction with highest resolution and it is still stabilised.

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 linear. Therefore, a calibration should be performed if the target shall be moved on a desired path.

Please consider the additional input and output options of sections 10.2 and 10.3 which can further improve the functionality of stabilisation systems with PSDs.

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 offer 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.

Note:

- The controller itself should not be placed in vacuum.
- The vacuum compatible detector does not have the LED displays on the backside. Therefore additional intensity outputs are integrated in the controller box.

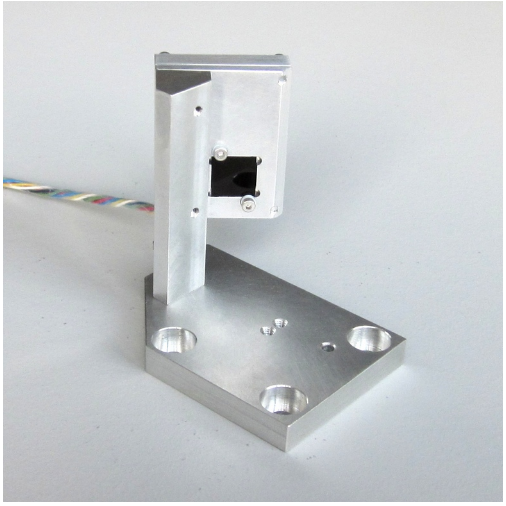


Figure 17: Vacuum compatible detector

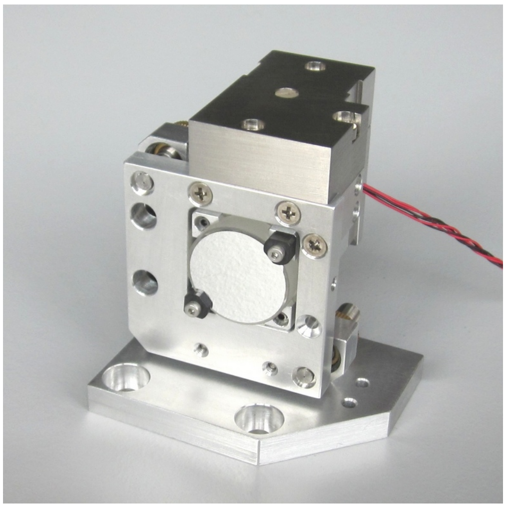


Figure 18: Vacuum compatible PSH actuator

4.4. Optical filters

We usually offer to integrate a pair of optical filters in front of each sensor. The filters have a size of 11.9 x 11.9 mm² and fit into the provided slot in the detector housing.

5. Installation and operation

5.1. Brief “step-by-step” instruction

The following steps shall assist you during the first startup of the beam stabilisation. The following sections will then explain the single steps more comprehensively.

1) Before use: The components should be stored in a dry environment for at least 24 hours.
2) Robust set-up of optical components (steering mirrors and detectors): The centres of the detectors define the beam position. The detectors can be placed directly behind mirrors. Alternatively, a small portion of the beam can be deflected to the detectors by means of a beam splitter.
3) Cable connection: First mirror with output *Actuator 1*, second mirror with *Actuator 2*. First detector with input *Det1*, second detector with input *Det2*.
4) Switch on power supply (switch on the left side of the housing): Thereupon the four green *Range* LEDs will shine at the controller box.
5) Adjustment of intensity on detectors (by means of the potentiometer and if necessary exchange of optical filters): In the best case 9 LEDs should shine.
6) Pre-adjustment (with non-activated control stages): Adjustment of the laser beam onto the detectors. After this step no red LEDs of the position display (LED cross) should shine.
7) Direction coding: Activation of control stage 1. If red *Range* LEDs are shining on the controller box the switch position for x or y direction should be changed (see section 5.6).
8) Direction coding according to step 7, now for stage 2.
9) Fine-tuning for control stage 1: Deactivate both control stages (*Active* LEDs do not shine). Then follow the description in section 5.7 until the x and y position outputs are close to 0 V.
10) Fine-tuning for control stage 2: Activate stage 1 (stage 2 is still deactivated). Then proceed according to section 5.7. After that the Piezos will have the widest range in each direction.
11) P-factor adjustment according to 5.8. Turn potentiometers P1/P2 clockwise until the system starts to oscillate. Then turn the potentiometers back far enough to ensure an oscillation-free operation.
12) For the stabilised operation of 4 axes activate both stages.

5.2. Introduction

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 switched on and off independently by pressing the *Start/Stop* button. If 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 although it might be 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 controller box with the connectors, the *P factor* adjustment and the switches for the *Directions* and the *Bandwidth* selection. The cables for 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 controller 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.

5.3. Set-up of optical components

The optical components (steering mirrors and detectors) can be configured 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 4.2.4. 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 that frequency.

The following figures 19-23 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 19 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 20 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.

- In figure 21 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 of our standard 4-QD is 30 µm.)

- Figure 22 shows a variation of 21 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 23 finally shows a different 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.

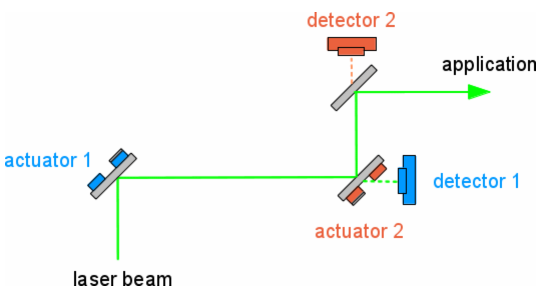


Figure 19: Typical sequence of components for the 4-axes stabilisation: Detector 1 stabilises the beam position on actuator 2. Detector 2 then defines the beam position at a separate point and hence the direction.

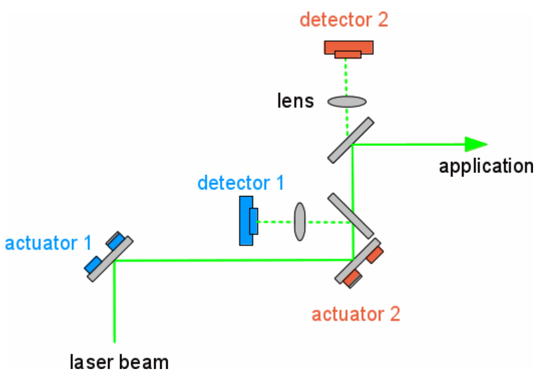


Figure 20: Set-up as in 19, with an additional beam splitter and a lens in front of detector 1 and an additional lens in front of detector 2 (Often used for lasers with larger beam diameters)

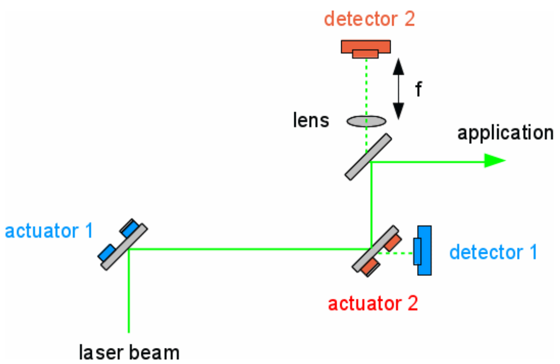


Figure 21: Set-up as in 19, but a lens is used to discriminate the angle by means of detector 2. This can be of advantage in case of restricted space with small distances between the optical components. Detector 2 must be placed in the focal plane of the lens.

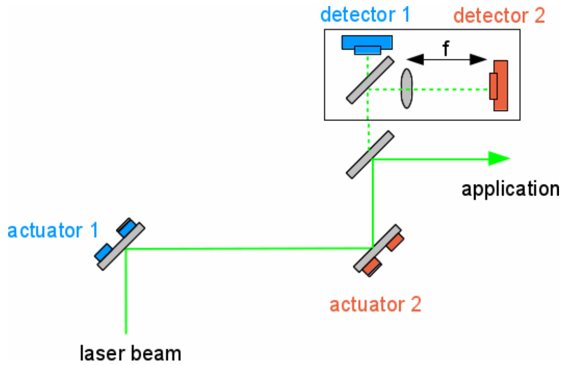


Figure 22: This set-up shows a variation of figure 21. Both detectors are placed behind the same mirror in order to measure both, the beam position and the direction at the same point. A lens is placed in front of detector 2 which discriminates for the angle.

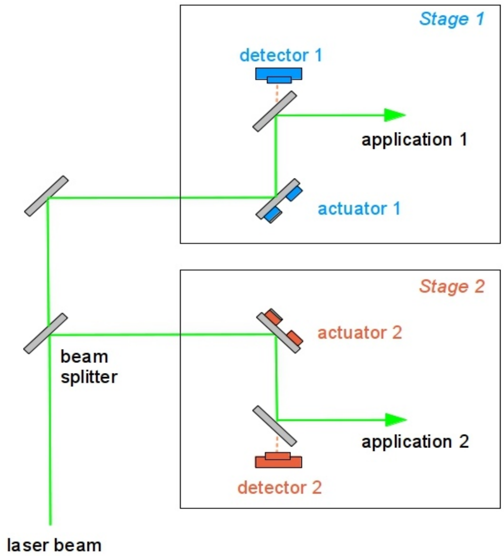


Figure 23: Set-up of a 4-axes system used as two 2-axes systems. With this set-up the position of two independent lasers can be stabilised with one controller.

Note: 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 surface.

5.4. Inputs and outputs

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

The connection of the detectors to the controller unit is made by 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:

- The PKS mirror mounts can be mounted in two orientations rotated 90° to each other. On delivery, they are labelled so that the x-axis performs the horizontal tilt and the y-axis the vertical tilt. Should you ever change the orientation yourself, please ensure that the horizontal tilt is always connected to the x input and the vertical tilt to the y input of the controller electronics.
- In case of the 2-axes system you can either use the first or the second stage for stabilisation.

5.5. Intensity adjustment

5.5.1. Adjustment of sensitivity with 4-QDs

To make sure that the detectors operate in the linear range, the power level can be adjusted by tuning the potentiometer for intensity variation (see figure 24). 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. The amplification increases by counter-clockwise rotation. 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.

If you do not find an appropriate adjustment you have to exchange the optical filters in front of the 4-QDs (see section 5.5.3). If the required filters are not available please contact the manufacturer or distributor.

Notes:

- In a standard delivery we integrate two optical filters in front of the sensor area. These are filters with a high and a low density for coarse and fine adjustment, respectively. Usually the filter which is the first to be reached is the low density one.
- Please be aware that the sensor area is quite sensitive. If you want to clean it you should do this carefully with a lint-free cloth.

Figure 24: 4-quadrant-diode. The arrow points to the potentiometer for intensity variation (Please use a screwdriver)

5.5.2. Adjustment of sensitivity with PSDs

The only difference to the adjustment of 4-QDs is that the PSDs have small push-buttons instead of the potentiometer. The adjustment can be carried out with the delivered metal pin by means of soft pushing. There is a small push-button for each direction behind the bores in the housing (see the arrows in figure 25). With the upper push-button you can increase the gain step by step, with the lower push-button you can decrease it. There are 64 steps between the highest and the lowest gain. This corresponds to a change of the sensitivity by a factor of 20.

If you do not find a fitting adjustment, you can exchange the optical filters in front of the PSD sensors.

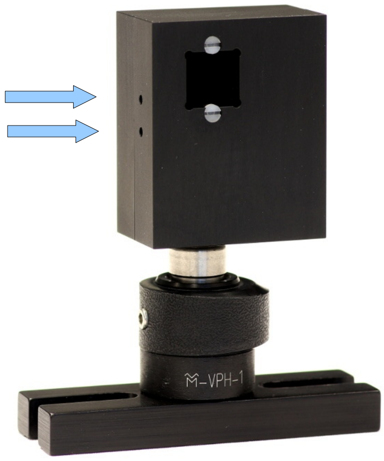


Figure 25: PSD detector. The arrows point to the push-buttons of the digital potentiometers for the gain adjustment (which can be carried out with the delivered metal pin)

5.5.3. 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 open 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.

5.6. Direction coding of detector outputs

For any deviation of the laser beam position on a detector the respective steering mirror is tilted in that way that it adjusts the laser beam back to the desired position. Each control stage makes use of a steering mirror and a detector as described in sections 5.2 and 5.3. The components that are working together are identically coloured in figures 19-23. 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 pre-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 switch on 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. Optimisation of laser beam position on detectors

i. Coarse adjustment (Obtaining linear range of steering mirrors):
   Activate the controller module (*Start* button switched on, green *Active*-LED and LED on button shining) and adjust the laser beam onto the detectors by means of manually tilting the steering mirrors until the four *Range* signals on the Piezo amplifiers are shining green. Now the steering mirrors are operating in their linear range.

ii. Fine-adjustment (Obtaining zero position and full range of Piezo drives):
   Inactivate the controller module (Piezo drives are in zero position, green *Active*-LEDs are dark) and adjust the laser beam by means of manually tilting the steering mirrors in that way, that it hits the centres of the detectors. This can be done by reading out the x and y position outputs of the controller module or by observing the position display on the backside of the detector module. The

position outputs deliver a signal that directly depends on the deviation from the target position. You can easily display these signals on an oscilloscope. The better the correlation of desired position and zero position of the Piezo actuators, the smaller the position shift after activating the closed-loop control. It also ensures that the Piezo range is equal for all directions.

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

5.8. Adjustment and read-out 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 set-ups 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. The potentiometers are located at the side panel of the controller box (figure 7). They are labelled with *P1* and *P2*. 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, until the system reaches its stabilisation limits and starts to oscillate. The potentiometers should then be turned back to a level, where an operation without oscillations is guaranteed.

Notes:

- The optimal P factors of stage 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 an interface in the form of analog inputs for a remote setting of the P factors. The remote adjustment connectors are integrated into the controller 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.

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 module. Furthermore, a LED cross on the detector module 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 26.

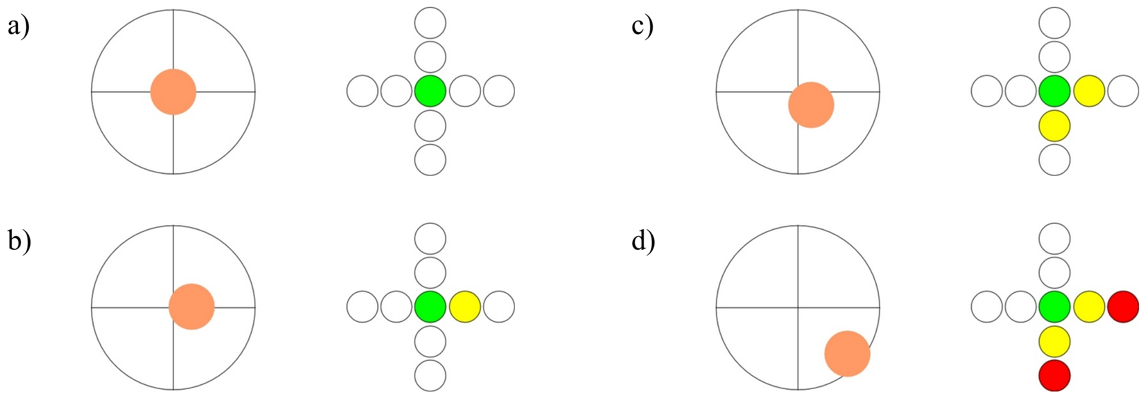


Figure 26: Examples for laser beams hitting the detector (orange spots) and the corresponding position display. The left pictures are shown in a view from the rear side of the housing to the sensor area.

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 two LEDs of LED line are on) the controller module 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 *PKS* and *PSH* Piezo actuators tilt the steering mirror into an extreme position. This is about 0.5 mrad (*PKS* mount) and 1.0 mrad (*PSH* mount) 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 when the controller module is active and the steering mirrors are in the correct range or in zero position. It is LOW if the module is active and 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.

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

Function: Fix the laser beam during laser off times

In some applications with the laser beam stabilisation the laser beam might be switched on and off during the operation. In laser off times there is no intensity on the detectors and hence no control signal for the closed-loop controller. In such situations, the *Compact* beam stabilisation without additional measures will drive the Piezo-driven steering mirrors into a defined position, the so-called zero position.

Once the laser is switched on again the stabilisation will start its operation from this position. The zero position should have been used for the first adjustment of the optical set-up. That is why this is usually a good starting point for the stabilisation. However, in cases of large drifts of the laser beam in the overall set-up, the zero position can – at least in the long term – strongly deviate from the required steering position. Switching on the laser after a time interval without laser beam and resuming of the stabilisation can therefore lead to an undesired initial spike of the beam position.

With the additional sample & hold circuit in the *Compact* beam stabilisation system 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.

The additional sample & hold (S&H) circuit is of special advantage for the following applications:

- In all systems where the laser must be switched on and off several times during the laser process, e.g. in material processing machines. Even if the system has drifted away from its basic adjustment, the beam position will start from the last stabilised position after resuming of the control loop. In this way an oscillation of the beam from the zero position to the desired position is eliminated and a potential faulty processing of the work piece is prohibited.

- In systems with a very large distance between the steering mirrors and the detectors. These set-ups bear the risk that a drift changes the adjustment in that way, that the laser beam will no longer hit the detector in uncontrolled intervals. Thus, it can happen, that the beam stabilisation can not catch the beam on the detectors after a resuming of the stabilisation when the laser was switched off for some time.

– In systems with very low repetition rates or lasers with irregular intervals of laser pulses (or pulse packages). If the S&H circuit of the beam stabilisation is triggered for each laser pulse, the beam position will get closer to the desired position with each pulse.

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
Sampling rate	25 kHz
Freezing interval	Unlimited
Requirement for automatic triggering	Minimal laser on time: > 100 ms
Trigger	
Signal levels	TTL, “high“ for laser on, “low“ for laser off
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

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 in laser on times and fix the position of the steering mirrors during intervals with no intensity.

For this automatic control the laser on intervals or the respective duration of pulse packages must be longer than 100 ms.

There is no need for the user to provide any trigger signals for this mode of operation.

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.

If the external triggering is used, the trigger signals have to be fed into the controller box via the respective LEMO connectors marked with “Trig” (see figure 27). 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 27: Left panel of controller 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. Figure 28 illustrates the respective tolerances of the trigger signal.

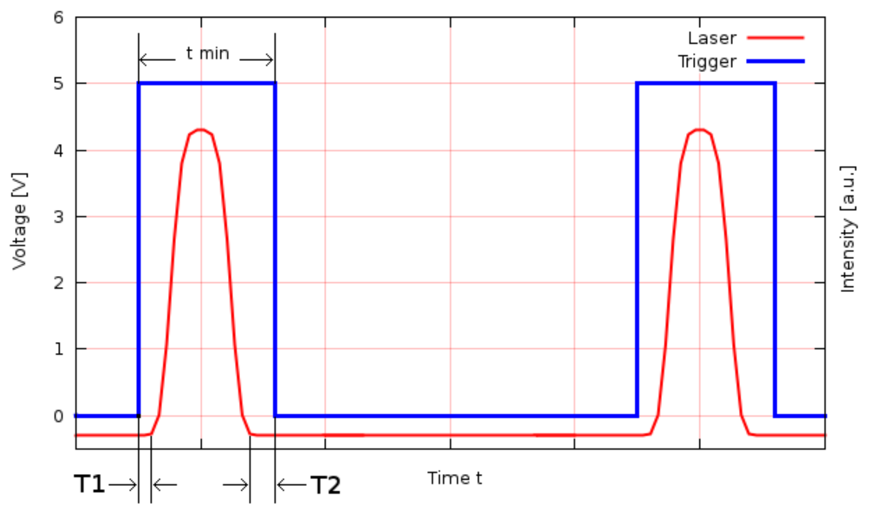


Figure 28: Timing of trigger signal

- Duration of trigger signal: $t_{min} \geq 10$ µs
- Start time of trigger in relation to start of laser on interval: -10 µs $\geq \tau_1 \leq$ 50 µs
- End time of trigger signal after end of laser on interval: $\tau_2 \leq$ 1 ms

The electronic requirements for the trigger signals are:

- TTL levels
- Level "high" when there is laser intensity on the detectors, level "low" when there is no intensity

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.

Notes: Please note that the last position of the steering mirrors is lost whenever the stabilisation system 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 29 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 30) 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.

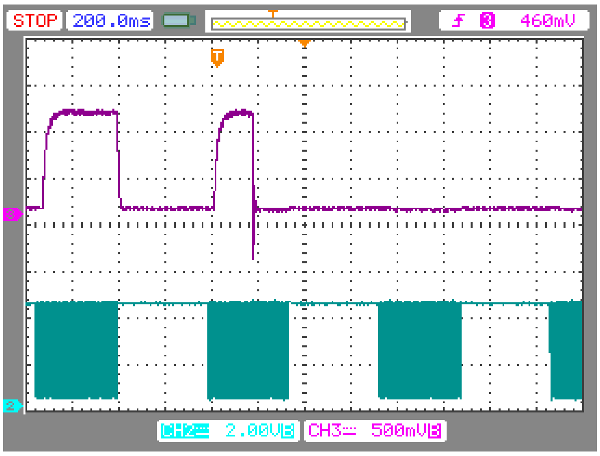


Figure 29: Activation of control-loop

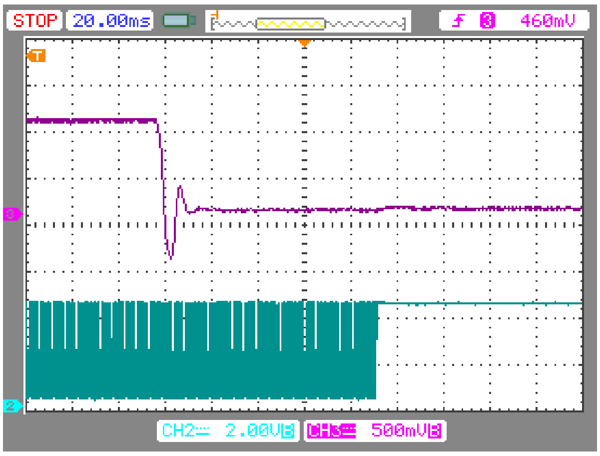


Figure 30: Enlarged view of figure 29

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 the applications mentioned in section 7 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.

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.

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 31 and 32 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 31 the laser is running without stabilisation. In figure 32 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.

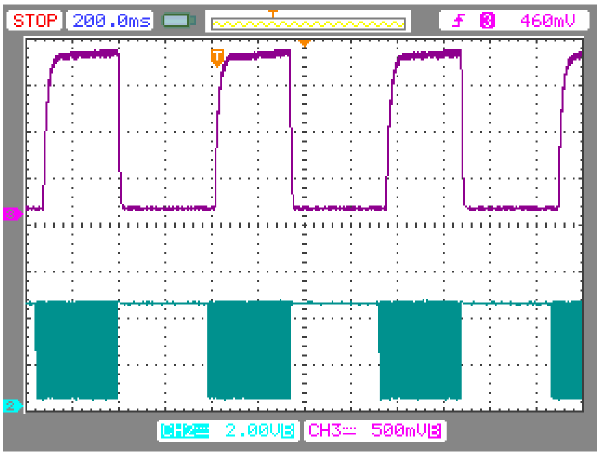


Figure 31: Pulse trains without stabilisation

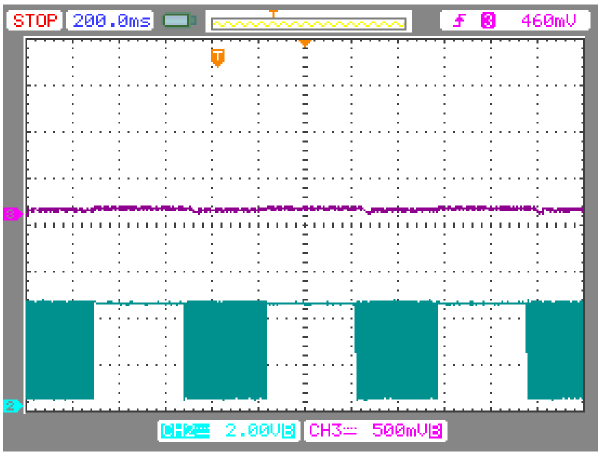


Figure 32: Pulse trains with automatic control

During the operation, the laser intensity should not be modulated by means of a laser shutter or another blocking component. Due to their functional principle the detectors would determine a wrong position for the short times of a partly blocked beam. Therefore the position signal would be distorted.

Note: The laser intensity should not be modulated by means of covering the laser beam. This can lead to wrong signals for the position of the steering mirrors.

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 33 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.

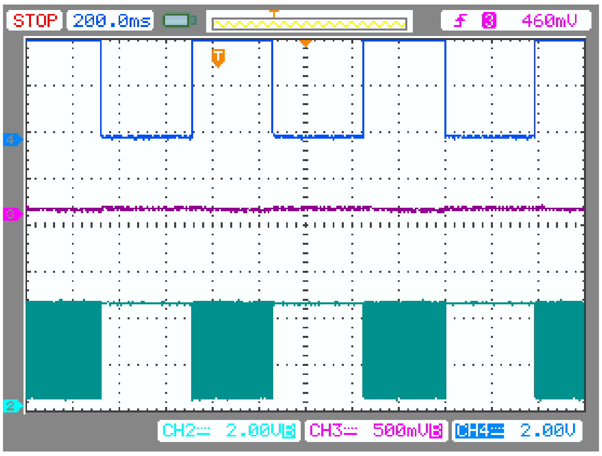


Figure 33: Pulse train stabilised with external trigger

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 34.

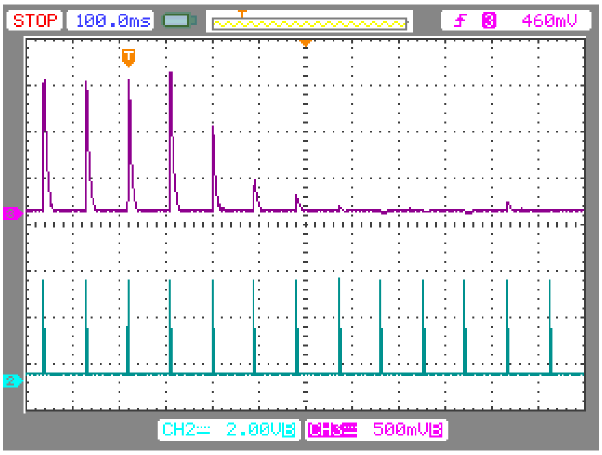


Figure 34: Single laser pulses (10 Hz)

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 was 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.

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 system can be equipped with a serial interface, for which we have defined a communication protocol. The protocol allows amongst others:

- the read-out of positions, intensities and Piezo voltages
- the read-out of the status
- switching on and off of the control loop via the software interface
- 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 of the protocol are available, which are also realized in the hardware, i.e. where e.g. the additional electronic circuits are integrated into the controller box.

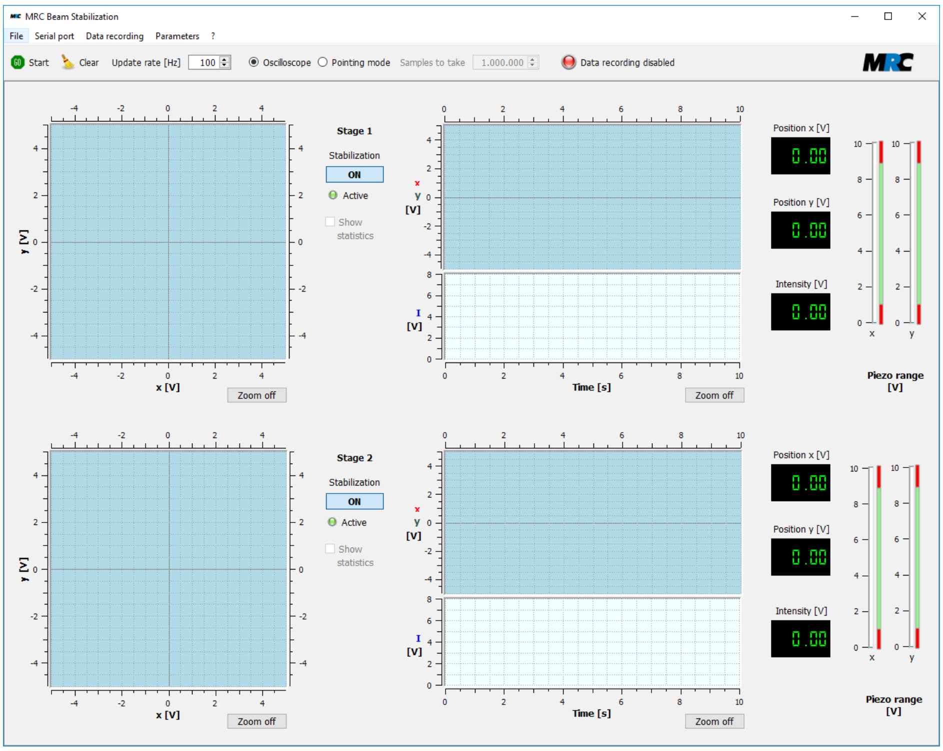


Figure 35: User interface of the communication and visualization software.

The option includes a software for visualization and communication. Figure 35 shows the main window of this software. If you want to learn more about the software, we can send you the comprehensive user manual. For integration with your own software we can provide you with the interface communication protocol.

9. Option: External activation

The external activation enables the change of the operation state of the beam stabilisation system with an external signal.

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

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 controller box. The inputs are marked as *Ext1* and *Ext2*.

10. 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:

- Status signal (see section 6.4)
- 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)

Other signal outputs or inputs can be provided as options.

Note: In some cases the arrangement of the connectors on the side panels have to be changed.

10.1. 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 specification of the voltage range for the *PKS* / *PSH* Piezo actuators is - 20 V to + 130 V. For the *P4S30* it is - 45 V to + 180 V.
- We have specified the voltages for the valid range of the green *Range* LEDs on the controller 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 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.

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

As described in section 4.2.4 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 36 shows the modified side panel of the controller box with additional inputs *Adj1* and *Adj2*.

Figure 36: Right panel with additional "Adjust-in" inputs for x and y position of two PSDs

Specification	
Description	2 analog inputs LEMO 3-pin, one for each actuator (x, y) or 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

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

10.3. Intensity outputs at controller

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

10.4. 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
Cable	LEMO 3-pin → 2x BNC, for each stage, length 2 m, 2 units

11. Drawings

11.1. Detector housing

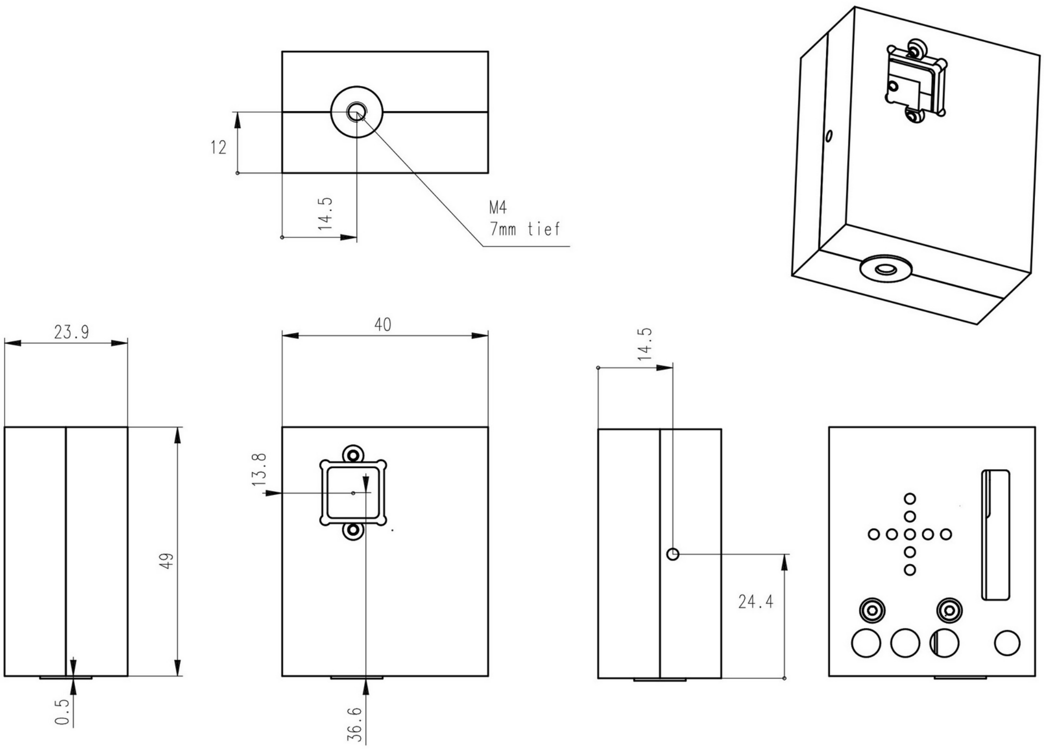


Figure 37: Standard detector housing

11.2. Mirror mount P4S30

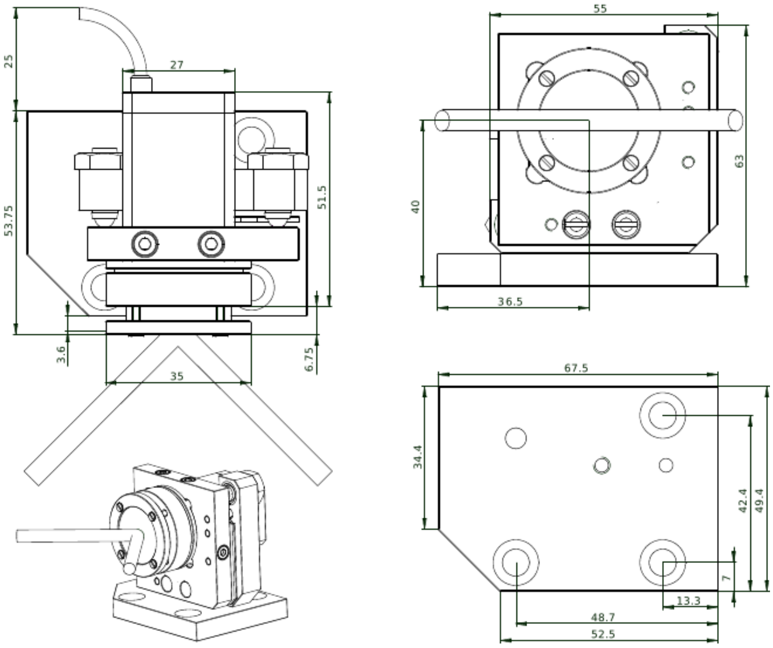


Figure 38: Mirror mount P4S30. For a better overview a typical path of a laser beam is displayed.

11.3. Mirror mount PKS

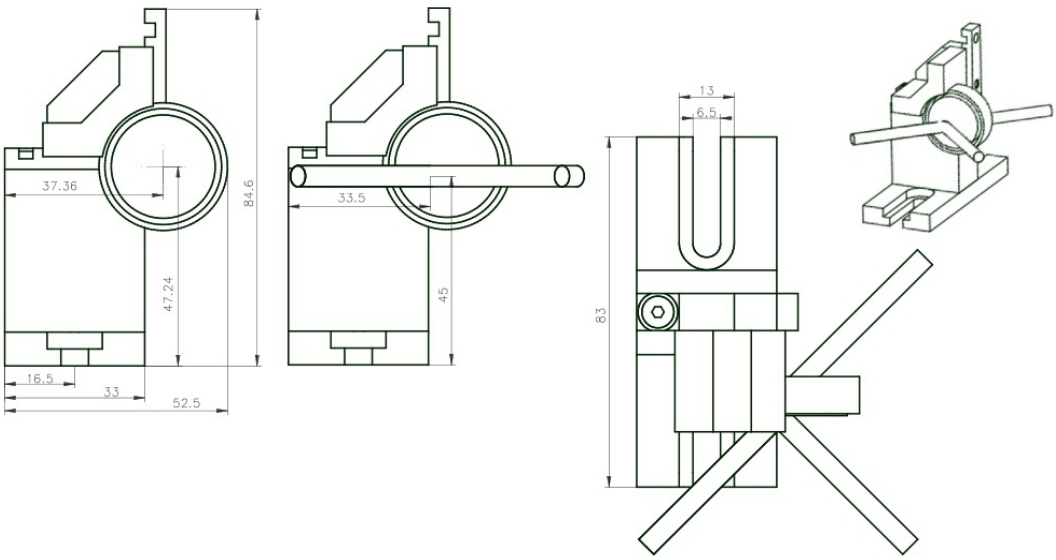


Figure 39: Mirror mount PKS. For a better overview a typical path of a laser beam is displayed.

11.4. Mirror mount PSH

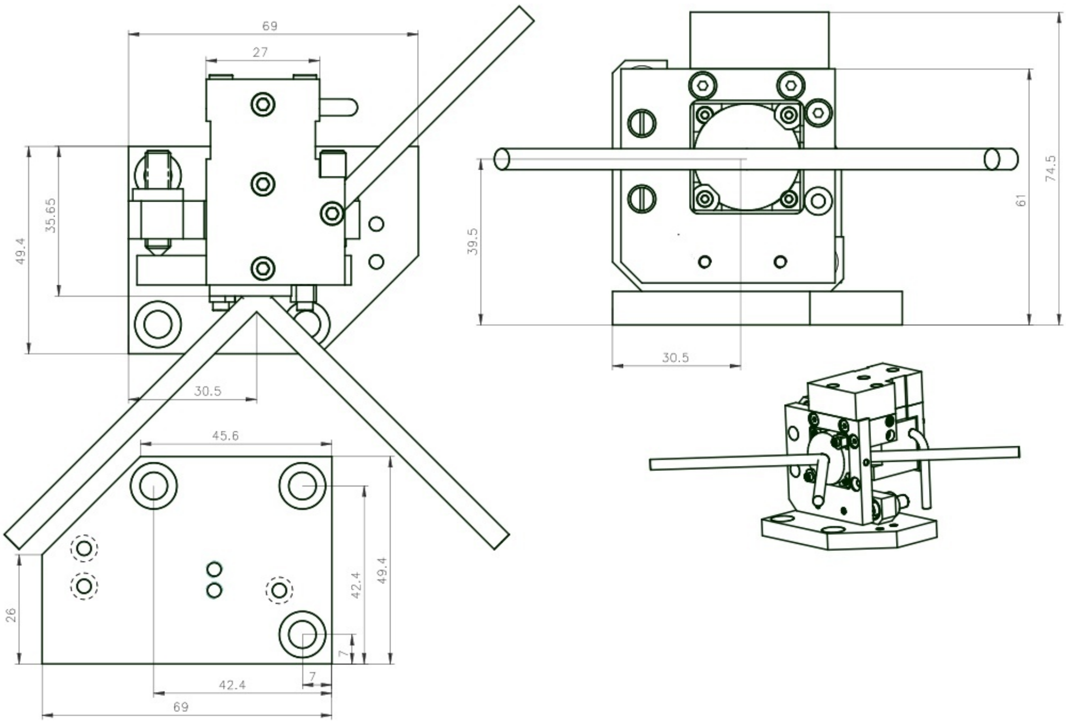


Figure 40: Mirror mount PSH. For a better overview a typical path of a laser beam is displayed.

We can send you the drawings and CAD files of the components on request.

12. Cables

12.1. 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	*PKS*: 1.5 m (directly mounted to Piezo element) *PSH*: 1.5 m (directly mounted to Piezo element) *P4S30*: 2 m (directly mounted to Piezo element)
Actuator → Controller (extension)	1	10 m
x, y position cable (LEMO → BNC)	2	2 m

12.2. 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 to connect the intensity output (LEMO → BNC)	2 m
Cable for P factor (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. Since we assemble various cables in-house we can customise almost any cable and cable length.

13. Troubleshooting

13.1. 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 the manufacturer or distributor.

13.2. No signals on detector

Please follow the instructions in section 5.5 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.

13.3. 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 5.4?
   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?

13.4. 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 5.5. 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 5.5 then.

13.5. 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).

14. 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

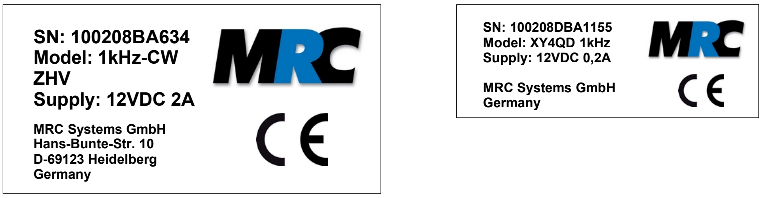


Figure 41: Labels on the controller electronics (left) and on the detectors (right)

15. Check list for laser data

For the final layout of the system and for an optimal support of your integration it can be helpful to know your laser and set-up data. You can send us your data according to the following compilation:

Customer: ....

15.1. Laser data

wavelength / range	....	
average laser power	....	
pulse duration	....	(fill in “cw” in case of a cw laser)
repetition rate	....	(not applicable in case of a cw laser)
beam diameter	....	
beam profile	....	(qualitative specs as “Gaussian”, „elliptical”, etc. are sufficient)

15.2. Set-up data

If possible, please send us a drawing or a photo of your intended set-up. We can then give you recommendations for the integration of the stabilisation system. We have our focus on an easy arrangement of the optical components and on appropriate distances between actuators and detectors (“arm lengths”) since they determine the reachable angular resolution.

15.3. Mirrors

Please let us know if we shall provide the mirrors:

Who will provide the mirrors? ☐ Customer

☐ MRC (on request, on account)

The following mirror sizes are recommended:

- standard: diameter 1", thickness 1/4" (1/8" as an alternative)
- on request: diameter 1.5" and 2"

16. Contact

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