I Multi-Axis Systems ZLM 800

The laser measuring head offers so much power, that several interferometers can be operated. The laser beam can be divided up by Intensity beam splitter (50%, 33% or 25%) on up to 4 measuring systems independent of each other. By the Evaluation unit AE 800 the signals are processed separately for every channel over a special software.
Fig. 1 describes a possible build-up of a two-axis systems with plane mirror interferometers.
At this arrangement are mounted two long plane mirrors by 90° angle on a XY-stage. The coordinates are valid under strict attention of the Abbé's principle for the crossing point of the two laser measuring lines. In this crossing point can align e.g. the axis of a microscope vertical to the measuring level or a 3D-sensor.
A maximum of accuracy is reached (also at possible pitch movements of the XY-stage).
This is a high degree of accuracy achieved in any tilting of the XY-stage.

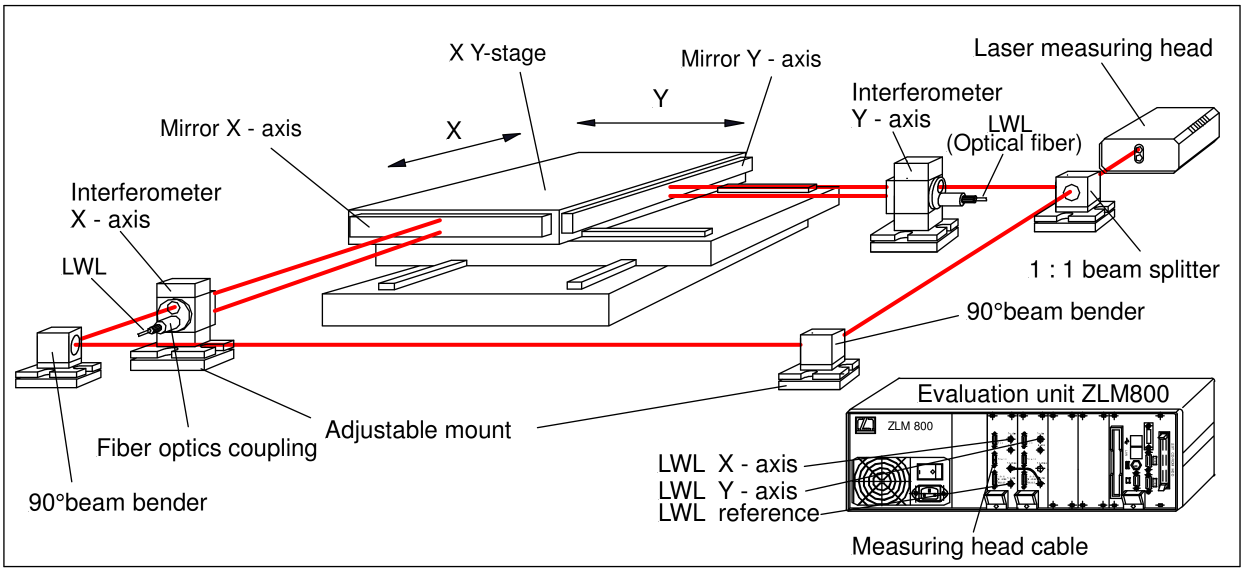


Fig. 1 : Configuration of a two-axis systems with plane mirror interferometers

1. Optical build-up

The module system ZLM 700/800 allows to build up a variety of variants in accordance with the need.
So it is possible to extend the build-up in Fig. 1 by a Z-axis or by an Angle interferometer detecting the pitch angle.

At the beam control of multi-axial configurations there is the possibility to lead one laser beam into the laser measuring head back. For further axes the beam control from the interferometer must be carried out via fibre optic cables. For the first case optical modules which can control two beams with a distance between each one of 15mm (standard) are necessary.

Therefore there are two groups of optical modules:

- **Optical modules for double beam**
- **Optical modules for single beam**

1.1.1. 90°Beam bender

The optical module consists of a plane tilted by 45°. The 90° angle must be adjusted by tilting of the optical module. The mirror coating is polarization neutral, i.e. the polarization of the laser beam remains unchanged

Fig. 2:
90° Beam bender 110
for double beam,
dielectrically polarization neutral mirror coating
Order - No.:   269302-4011.024

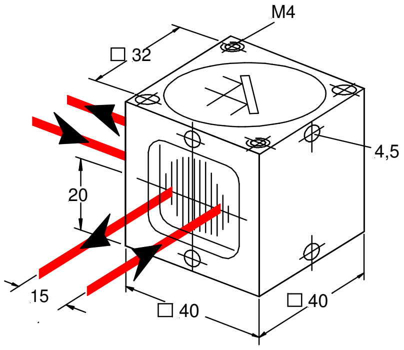
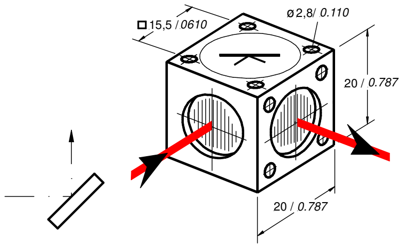


Fig. 3:
90° Beam bender 205
for single beam,
dielectrically polarization neutral mirror coating
Order - No.:   269302-4012.424



1.1.2. Intensity beam splitter

The intensity splitting of a laser beam is made by intensity beam splitter. The laser beam intensity being available shall be divided up on the same quotas for the individual measuring axes. This can be reached by combination with optical components of different dividing behaviour. Intensity beam splitter with higher quota reflection as the transmission are produced only with metal coating. *(Important: Intensity quotas are dependent on the polarization)*. In the following table the dividing behaviour of optical modules (into dependence of the polarization) are listed.

Fig. 4:
Beam splitter A
for double beam,
Order - No.: *see into the table 1*

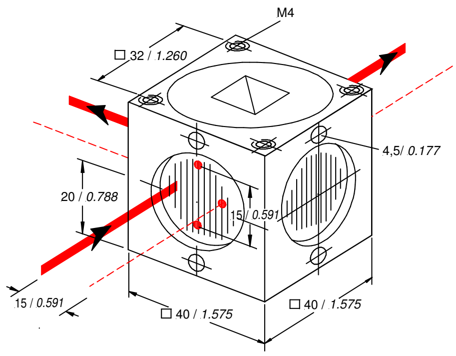
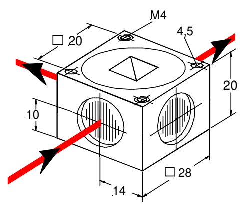


Fig. 5:
Beam splitter B
for single beam,

Order - No.: *see into the table 1*



Splitting ratio	Article-No.	R / % *(Reflection)*		T / % *(Transmission)*		Order-No.
with dielectric, polarizing neutral coating ⊥ vertically polarized || horizontally polarized						
A 1:1	201	⊥ 50	|| 50	⊥ 50	|| 50	269302-4011.424
A 1:2	212	⊥ 33	|| 33	⊥ 67	|| 67	269302-4017.824
A 1:3	211	⊥ 25	|| 25	⊥ 75	|| 75	269302-4017.624
B 1:1	203	⊥ 50	|| 50	⊥ 50	|| 50	269302-4012.124
B 1:2	210	⊥ 33	|| 33	⊥ 67	|| 67	269302-4017.924
B 1:3	209	⊥ 25	|| 25	⊥ 75	|| 75	269302-4017.724
with metallic coating						
A 2,5:1	207	⊥ 72	|| 61	⊥ 21	|| 32	269302-4011.724
A 4:1	202	⊥ 80	|| 70	⊥ 14	|| 24	269302-4011.824
B 2,5:1	208	⊥ 72	|| 61	⊥ 21	|| 32	269302-4012.324
B 4:1	204	⊥ 80	|| 70	⊥ 14	|| 24	269302-4012.224

Table 1: Overview of the intensity beam splitter

1.1.3. Interferometer

The interferometers are based on a building block concept.
In addition to standard components the modular system is completed with compact interferometer interferometers and custom interferometer designs. Contact us to help you choose the interferometer configuration that best suits your metrology problem meet.

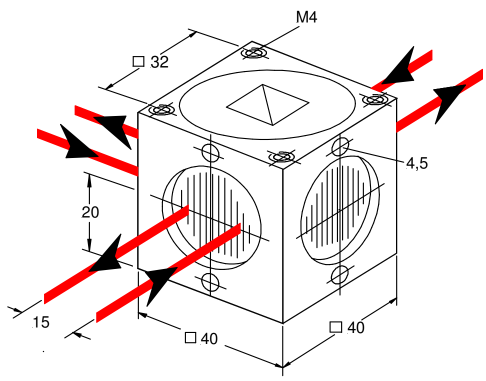


Fig. 6:
Polarizing beam splitter 101
Order - No.: 269302-4010.124

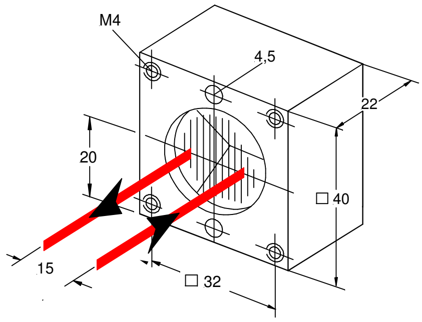


Fig. 7:
Cube corner reflector 102
Order - No.: 269302-4010.224

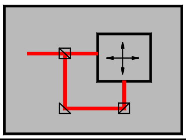


Fig. 8:
λ/4 – Plate 104
Order - No.:   269302-4010.424

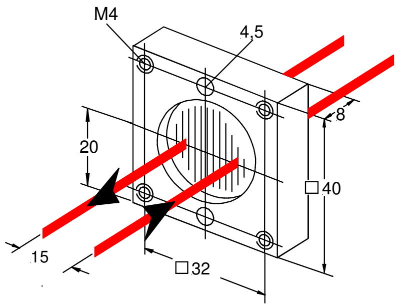


Fig. 9:
Fibre optics coupling 222
for Polarizing beam splitter 101
Order - No.:   269302-4015.724

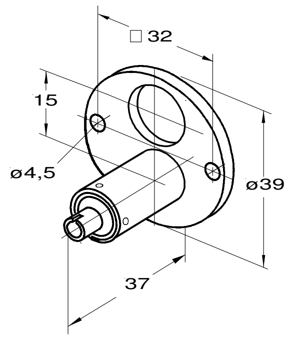


Fig. 10:
Angular interferometer 114
Order - No.:   269302-4015.324

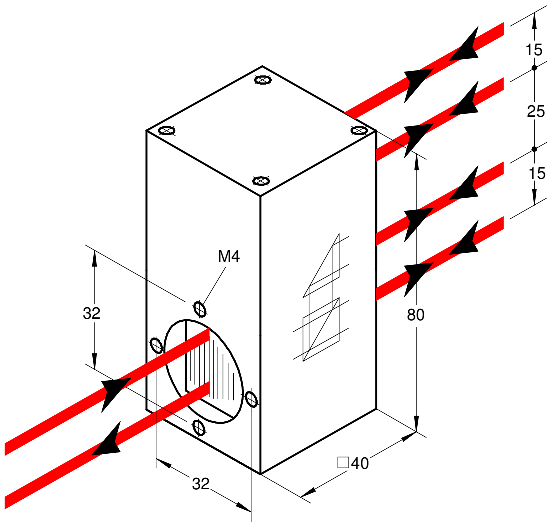


Fig. 11:
Configuration of Angular interferometer

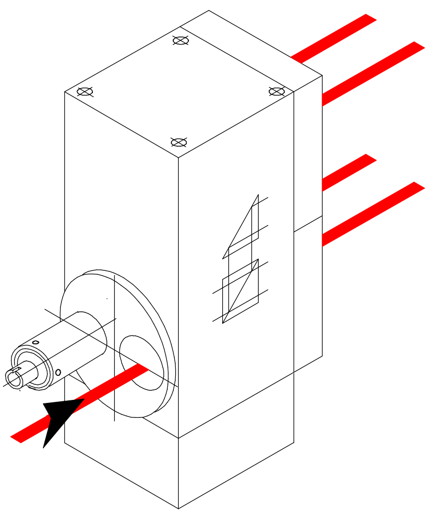
<u>*Consisting of:*</u>

Angular interferometer 114
Order - No.:   269302-4015.324

Cube corner reflector 102
Order - No.:   269302-4010.224

2 pcs of ***λ/4 – Plate 104***
Order - No.:   269302-4010.424

Fibre optics coupling 222
Order - No.:   269302-4015.724



In Figure 12 (a, b, c) a measurement arrangement is shown in which a movable measurement plane is moved relative to a fixed reference plane. Measured is the exact position and the tilt of the measurement plane relative to the reference plane in two axes.
Depending on requirements, the customer can choose between different types of interferometers.

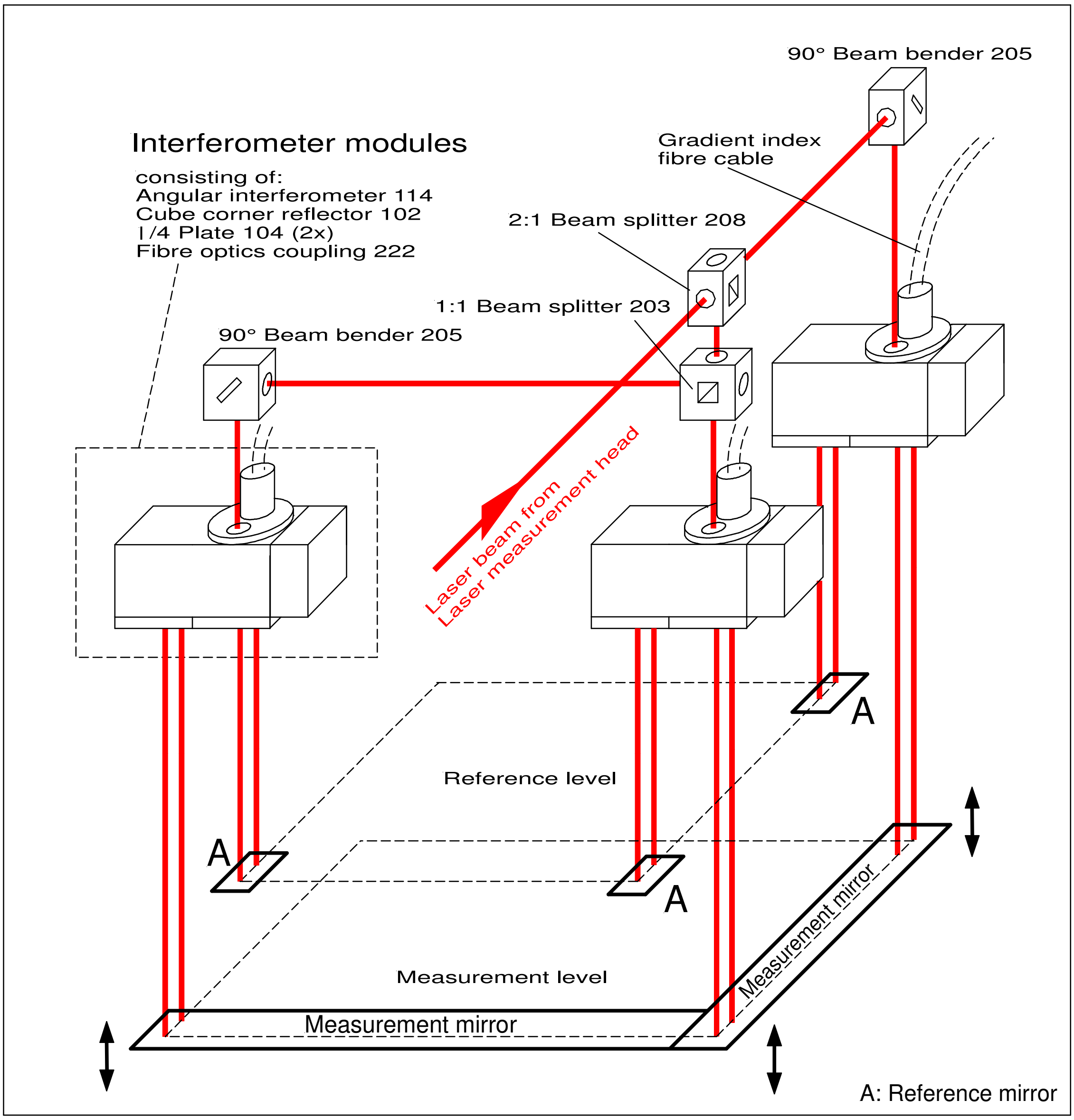


Fig. 12a: Multi-axis-arrangement (3 axes) realised with Angular interferometer

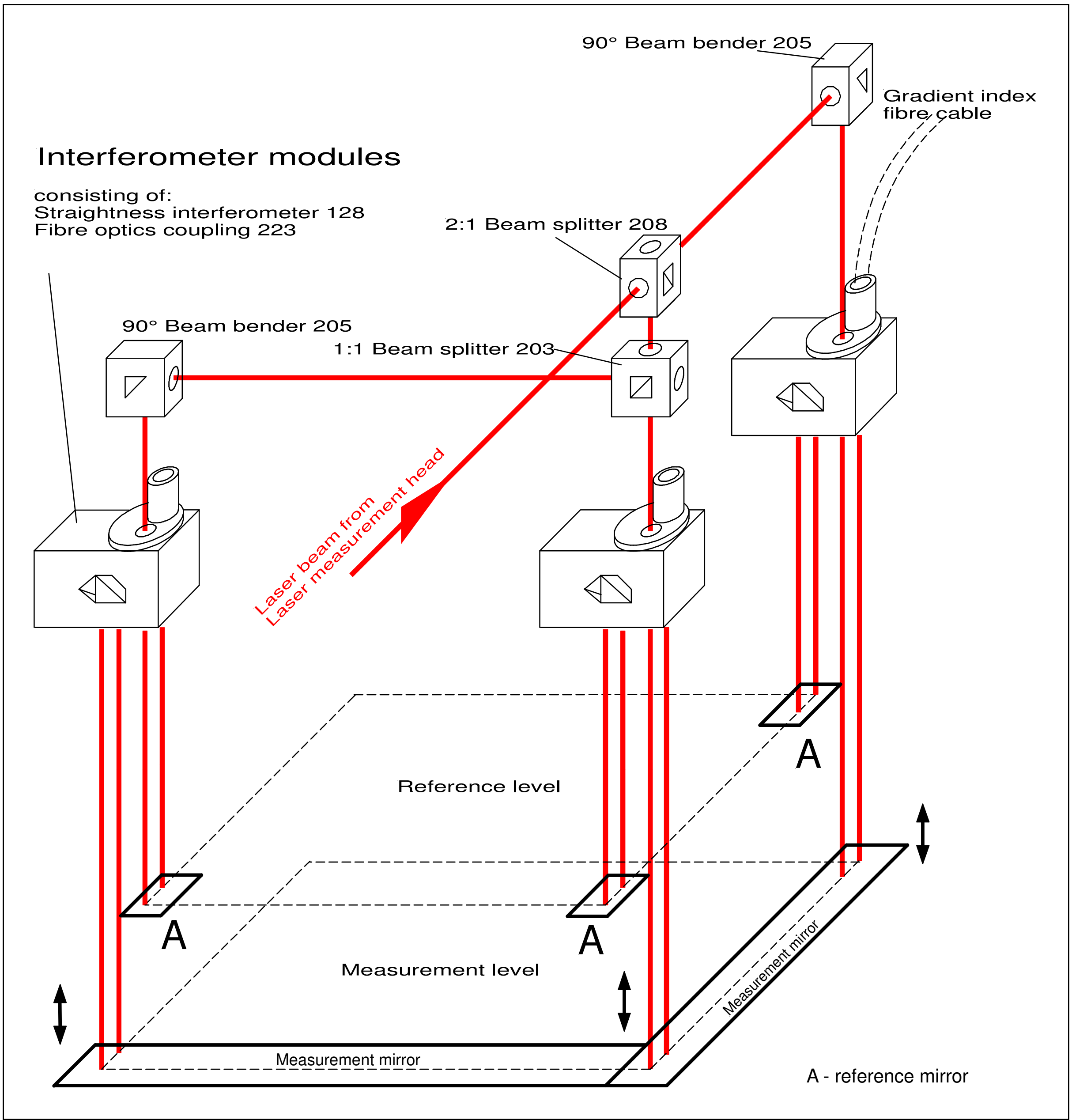
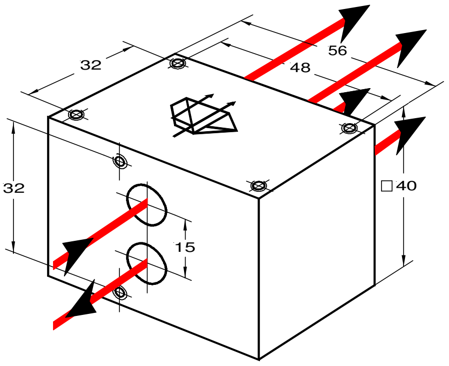


Fig. 12b: Multi-axis-arrangement (3 axes) realised with Differential interferometer 128



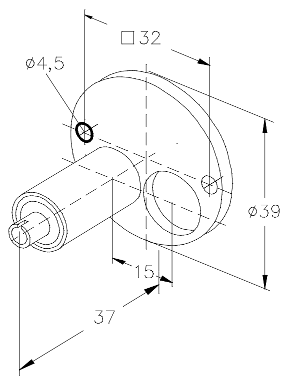


Fig. 13:

Straightness (Differential-) interferometer 128
Order - No.: 269302-4012.824

Fibre optics coupling 223
Order - No.: 269302-4015.824

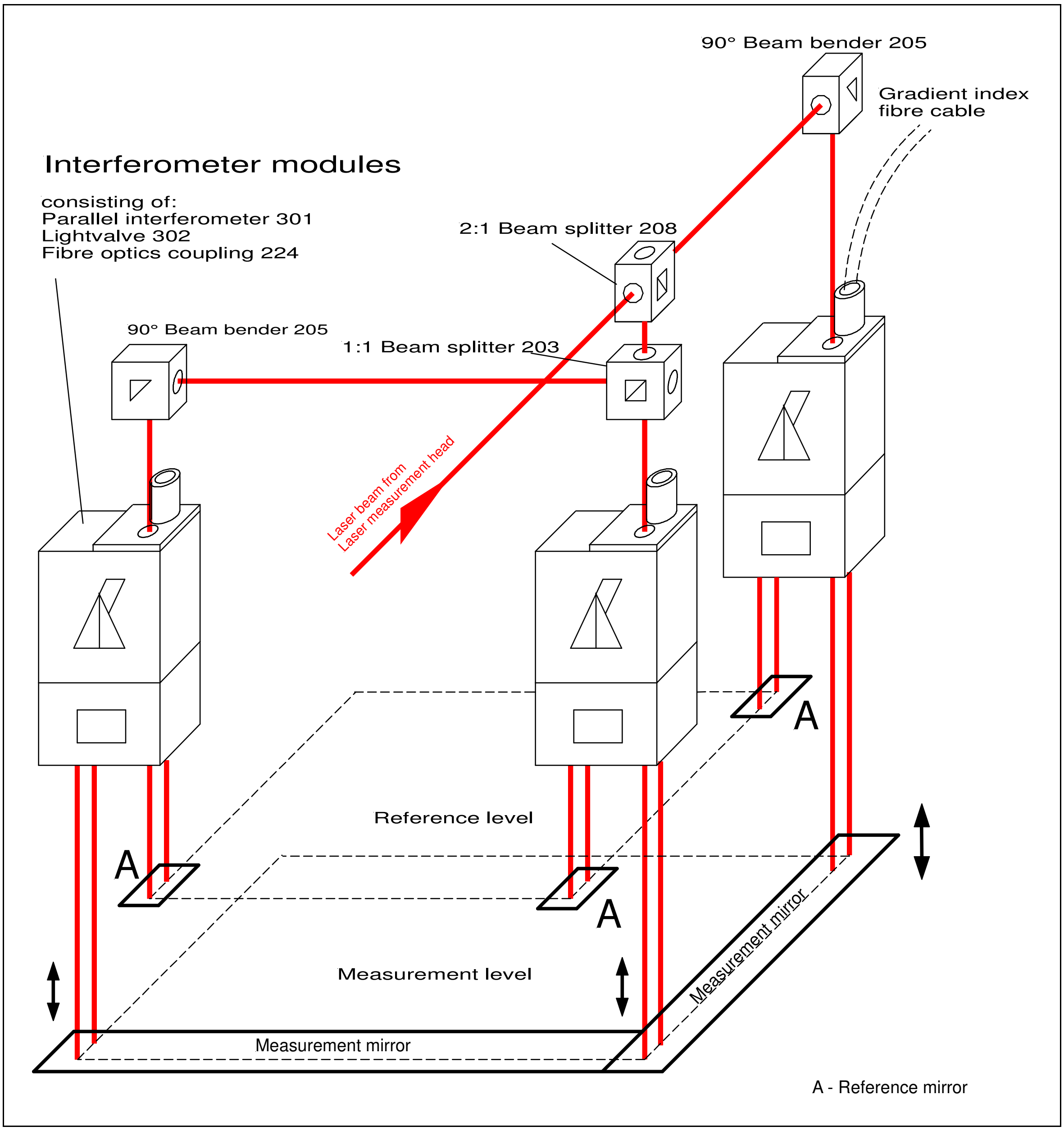


Fig. 12c: Multi-axis-arrangement (3 axes) realised with Parallel interferometer 301

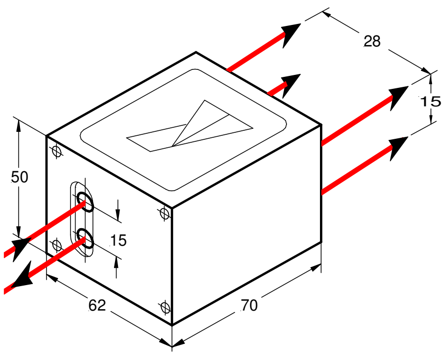


Fig. 14:
Parallel interferometer 301
Order - No.: 269302-4013.324

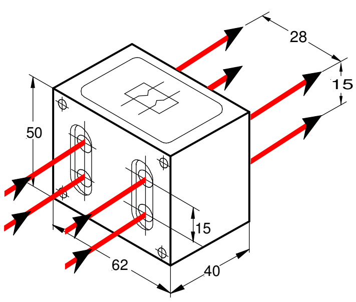
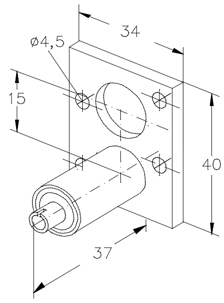


Fig. 15:
Light valve 302
Order - No.: 269302-4013.424

Fig. 16:
Fibre optics coupling 224
for Parallel interferometer 301
Order - No.: 269302-4015.924



1.2. Functional description of the Parallel interferometer

The part of the beam from the laser head has two orthogonally polarized modes of the frequencies f1 and f2 (fig. 17, 18).

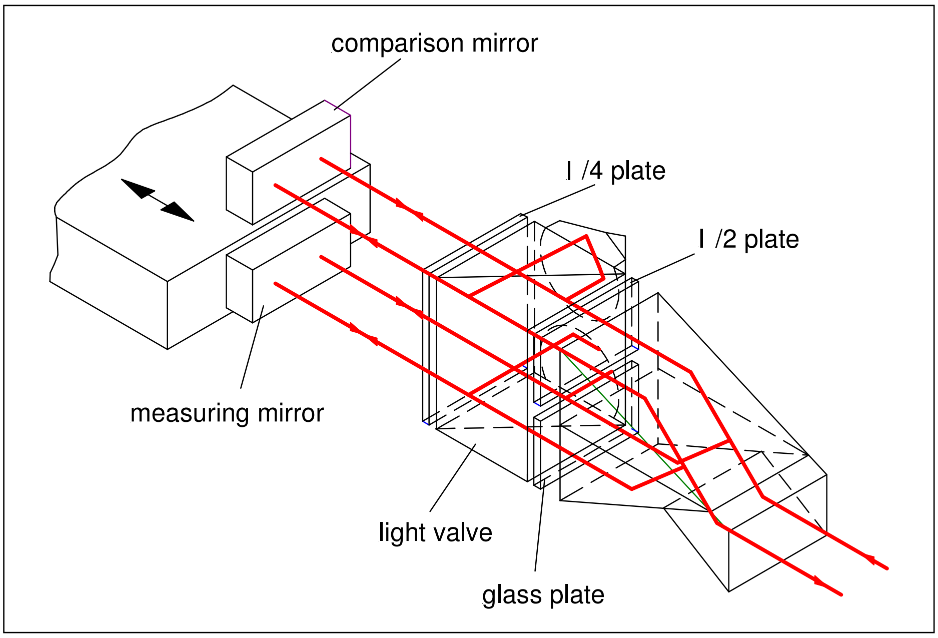


Fig. 17: Schematic diagram of the interferometer optics for difference plane mirror interferometers

The polarization-layer of "Köster" prism splits the light beam into a measuring beam with the frequency f1 and a reference beam with the frequency f2. Both partial beams reach the light valve.
One of the plane plates is a λ/2 plate which rotates the polarization plane of one partial beam 90°, so that both partial beams then vibrate in the same direction. The second plate does not have a polarization-optical effect, but just serves the preservation of the symmetry of the glass paths. Both beams are then passed through to the polarization dividing layer of the light valve. At the λ/4-plate both beams be transformed into circularly polarized light .
After reflection of the two partial beams at the plane mirrors, the λ/4 plates are passed again. The circularly polarized light again becomes linearly polarized light, but now with the polarization plane rotated by 90°. So that the light retroreflected to the dielectric layer of the light valve is no longer transmitted by it, but reflected into the direction of the triple prisms.
In the triple prisms the two partial beams are reflected parallely displaced and again reflected by the dielectric layer into the direction of the measuring and comparison mirrors. The partial beams are again circularly polarized through the λ/4 plate, reflected at the plane mirrors along the input path and, after traversing the λ/4 plate, again linearly polarized.

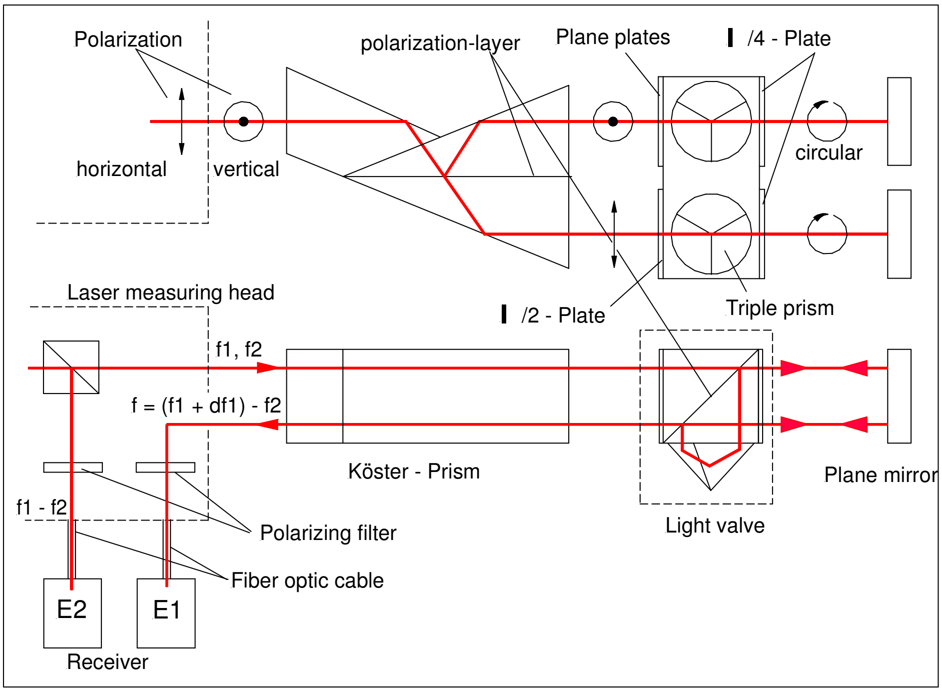


Fig. 18: Functional principle of parallel interferometer (“Köster interferometer”)

But now the polarization plane is rotated 90° in such a way that the two partial beams are transmitted by the dielectric layer of the light valve and thus can leave it. One partial beam is now again rotated on the λ/2 plate in its vibration plane, so that it is reflected at the polarization dividing layer of the Kösters prism and can interfere with the second partial beam transmitted there and directed to receiver E2 of AE800. The beam arrangement is so designed that both beams cover the same ways. A large metrological advantage of this arrangement lies in the symmetry of the beams.
If the plane mirror is not moving, the receiver E1 detects the difference frequency of the laser f1 - f2 = 640 MHz which is equal to the reference signal E2 detected in the laser head.
If one or both plane mirror is moved against each other, then develops between the partial beams due to the changing optical path lengths a Doppler shift ± df1.
Accordingly, detector E1 registers a measuring frequency of +df1 or -df1, depending on the moving direction. The two signals detected (E1 and E2) are compared with each other in the high-frequency section of the laser interferometer system. The result obtained is the frequency shift *df1 due to the Doppler effect; this shift is a measure of the path of the measuring reflector, from which the displacement of the measuring reflector is counted. The double reflection at the plane mirrors realizes at the same time an optical fourfold interpolation. The fourfold way off the laser beam results by movement off the measuring mirror in optical configuration a resolution off 1.25nm.

1.3. Adjustable mount for optical modules

The following adjustable devices serve to mounting the optical modules:

Fig. 19:
Adjustable mount 588 for optical components □ 40

Order-No.: 269302-4009.025

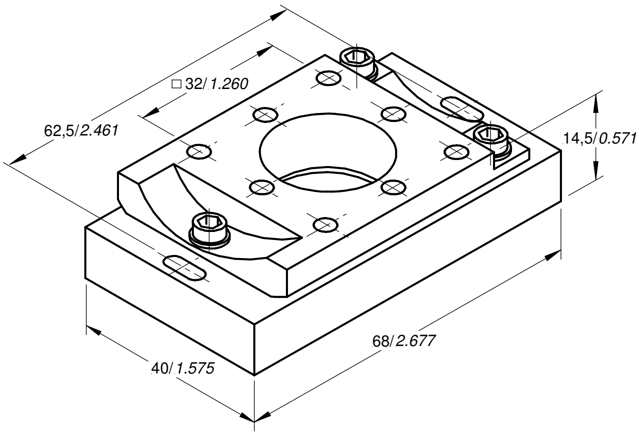


Fig. 20:
Adjustable mount 589 for optical components □ 28
Order-No.: 269302-4009.125

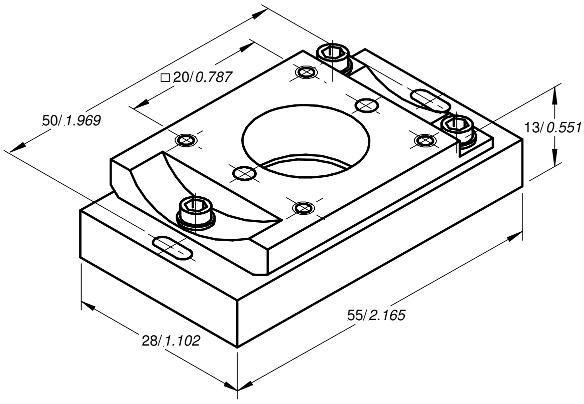
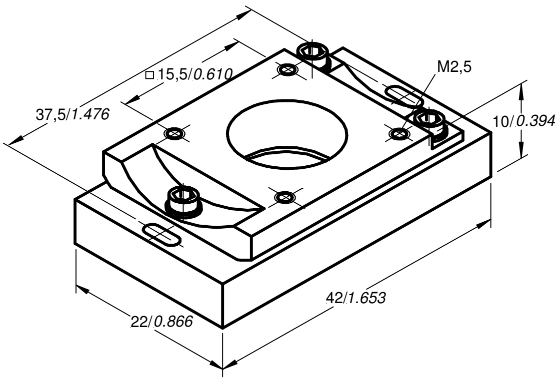


Fig. 21:
Adjustable mount 590 for optical components □ 20
Order-No.: 269302-4009.225



1.4. Compact interferometer 344 for 3axis measurement (Triangulation)

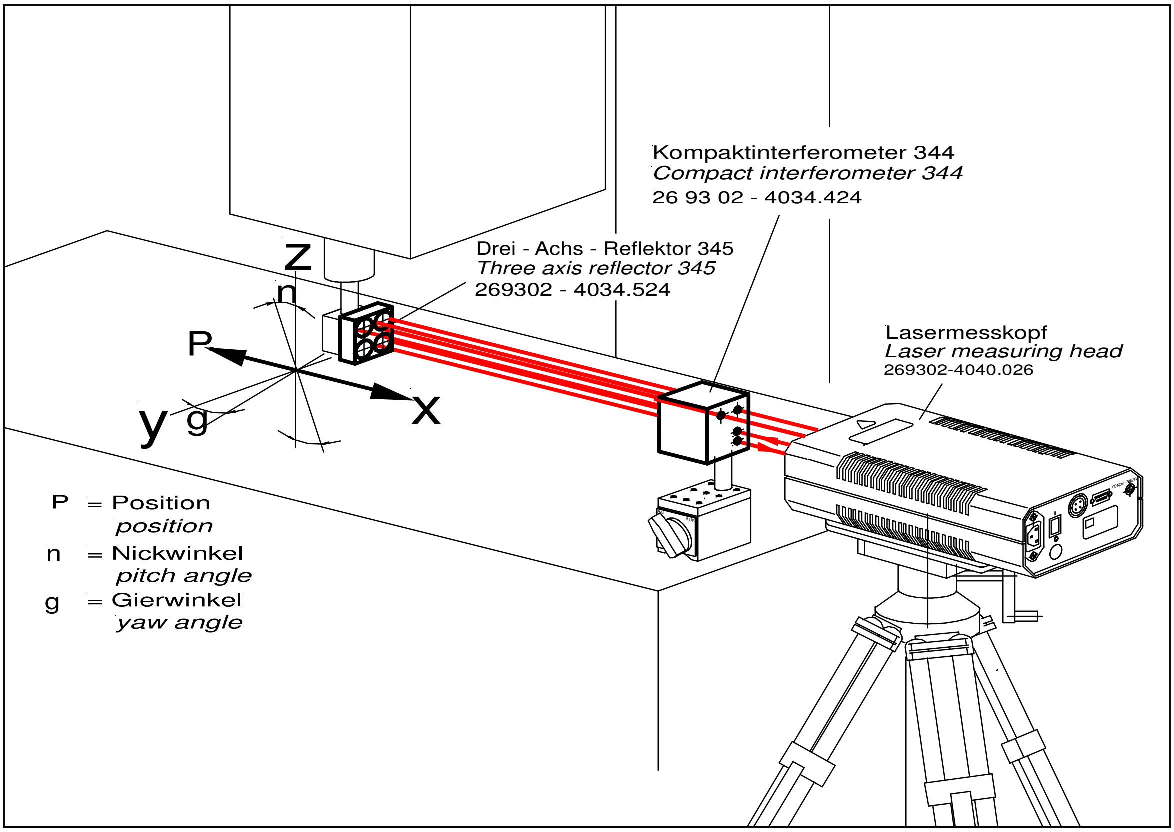


Fig. 22: Simultaneous position, pitch angle and yaw angle measurements in one axis direction

Fig. 23:
Compact interferometer 344
Order-No.: 269302-4034.424

1, 2 and 3 are the outputs of the interferometer

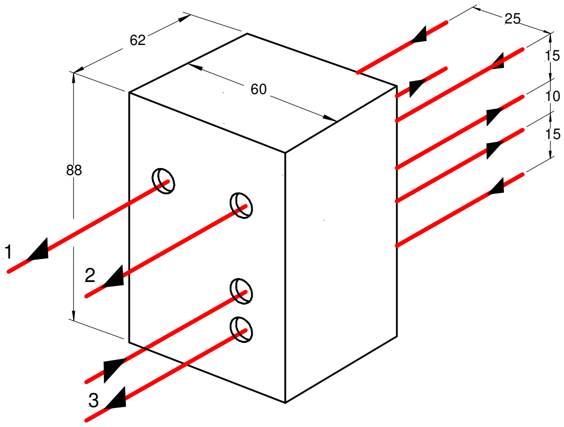
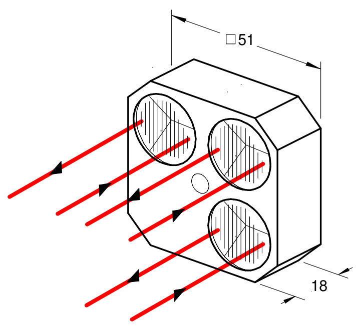


Fig. 24
Three axis reflector 345
Order-No.: 269302-4034.524



2. Evaluation unit AE 800

2.1. AE 800cPCI/PXI

The most essential components of the evaluation unit are:

- 19" – 3HE box system for 1 - 4 axis, optionally 6 – 8 axes
- CPCI (PXI) – backplane for 8 slots (optionally to 24 slots)
- 1 - 4 interpolator assembly (according to quantity of interferometers)
- cPCI/PXI processor insert Pentium M, 1.2GHz + operating system WINDOWS 2000/XP/7
- 1 Control unit with RS-232 and CENTRONICS interface
- Interfaces for
  - keyboard, mouse, monitor
  - Ethernet, LAN, USB1/2, RS 232, IEEE 488, optionally external drive
- Hardware interfaces of interpolator assembly:
  - 32 bit real-time counter signals (15ns)
  - AQB – counter input for e.g. Heidenhain scales (20MHz)
  - AQB – counter output for Motion control (10MHz)
  - 16 x 12 bit ADC - inputs
  - external trigger in / trigger out
  - external zero setting

Fig. 26 shows the view and the interfaces of the evaluation unit AE 800 cPCI-PXI.
The interfaces of the front can be divided into interfaces for data exchange with other units and interfaces, that are necessary for operating the laser measurement system.

2.1.1 Interfaces for operating of the laser measurement system

Laser measuring head	Laser measuring head cable to the laser measuring head, (for display the quality of the alignment of reference and measurement beam)
AUK	AUK Connection cable
IF - in	Connection of the Fibre optic cables of each interferometer axis (per axis 1x)
Ref - in	Connection of the Fibre optic cables of the reference beam of the laser measuring head
Ref - in/out	Connections of the cables for the reference signal of the laser measuring head of each measuring cassettes

2.1.2. Interfaces for electronic data interchange

Mouse and keyboard connection	Mini DIN 6 Pin mouse and keyboard connector (PS/2)
Monitor connection	Monitor port
IDE interface	external connection for an additional EIDE device ((Hard disk, CD, disk drive)
Serial Interface	data interchange with external units (2 serial ports RS232) to a higher-level computer
IEEE 488 or SCSI	data interchange with external units (optionally)
IF32 Axis (optionally)	32 Bit-Realtime-Interface (to get a current position count value of the two's complement with Reset and Trigger function)
A-Q-B counter-input 2. counter	Counting the digital pulses from a Heidenhain scale (0, 90°, 180°, 270°)
A-Q-B counter-output	serial supply of laser position data (0, 90°, 180°, 270°) for Motion control

The most important interfaces to the user and the operation of the unit are described in the "Software manual".

2.2. AE 800 PCI

For standard PCs, industrial PCs and portable PCs, there is the possibility of assembly with

AE 800 PCI/Master	for the first measuring axis and
AE 800 PCI/Slave	for each additional measurement axis

Electrical operating conditions and interfaces are the same like the compact PXI variant.

2.3. Basic equipment for multi-axis laser interferometer systems ZLM800

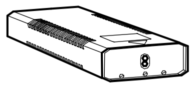
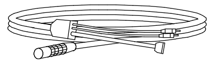
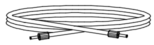
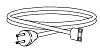
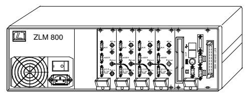
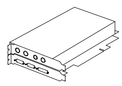
Laser measuring head 269302-5041.026		Quantity: 1
Measuring head cable 269302-4040.124		Quantity: 1
Gradient index fibre cable 212.678		Quantity: 1 per axis
Power cord 146.250		Quantity: 1
Evaluation unit AE 800: **AE 800cPCI-PXI** 1 Measuring axis **.../1S** 269302-5070.126 2 Measuring axes **.../2S** 269302-5070.226 3 Measuring axes **.../3S** 269302-5070.326 4 Measuring axes **.../4S** 269302-5070.426		Quantity: 1
or **AE 800 PCI** 1 Measuring axis **.../Master** 269302-5071.026 for each additional measuring axis **.../Slave** 269302-5071.526		Quantity: 1 Quantity: 1 per axis

Fig. 25: Basic equipment for multi-axis laser interferometer systems ZLM800

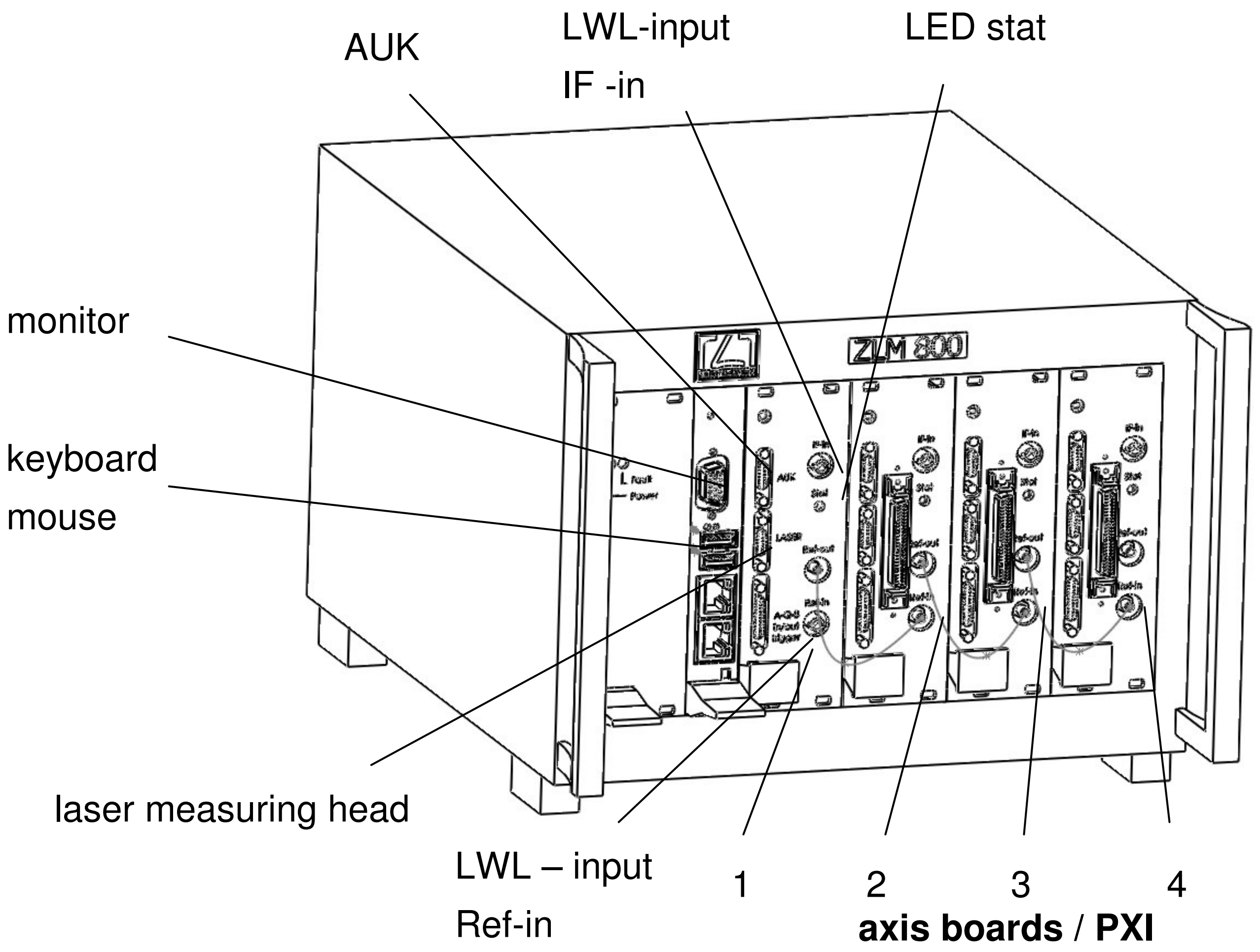


Fig. 26: Evaluation unit ZLM800 cPCI/PXI

3. Assembling and adjustment of Multi-axis-systems ZLM800

3.1. Necessary function requirements

For perfect function of the laser measuring system the following requirements must be met:

1. By using beam splitters the laser beam is divided and directed into different paths. The beam is always directed parallel or perpendicular to the Laser measuring head’s axis. The splitting of the laser beam on each axis should be made so, that each axis is given the same amount of light .
   In Figure 27, a selection of variants is shown, that is allowed by the ZLM modular system.
   (Beam splitter see figures 4/5 page I-2 and table 1 page I-3)

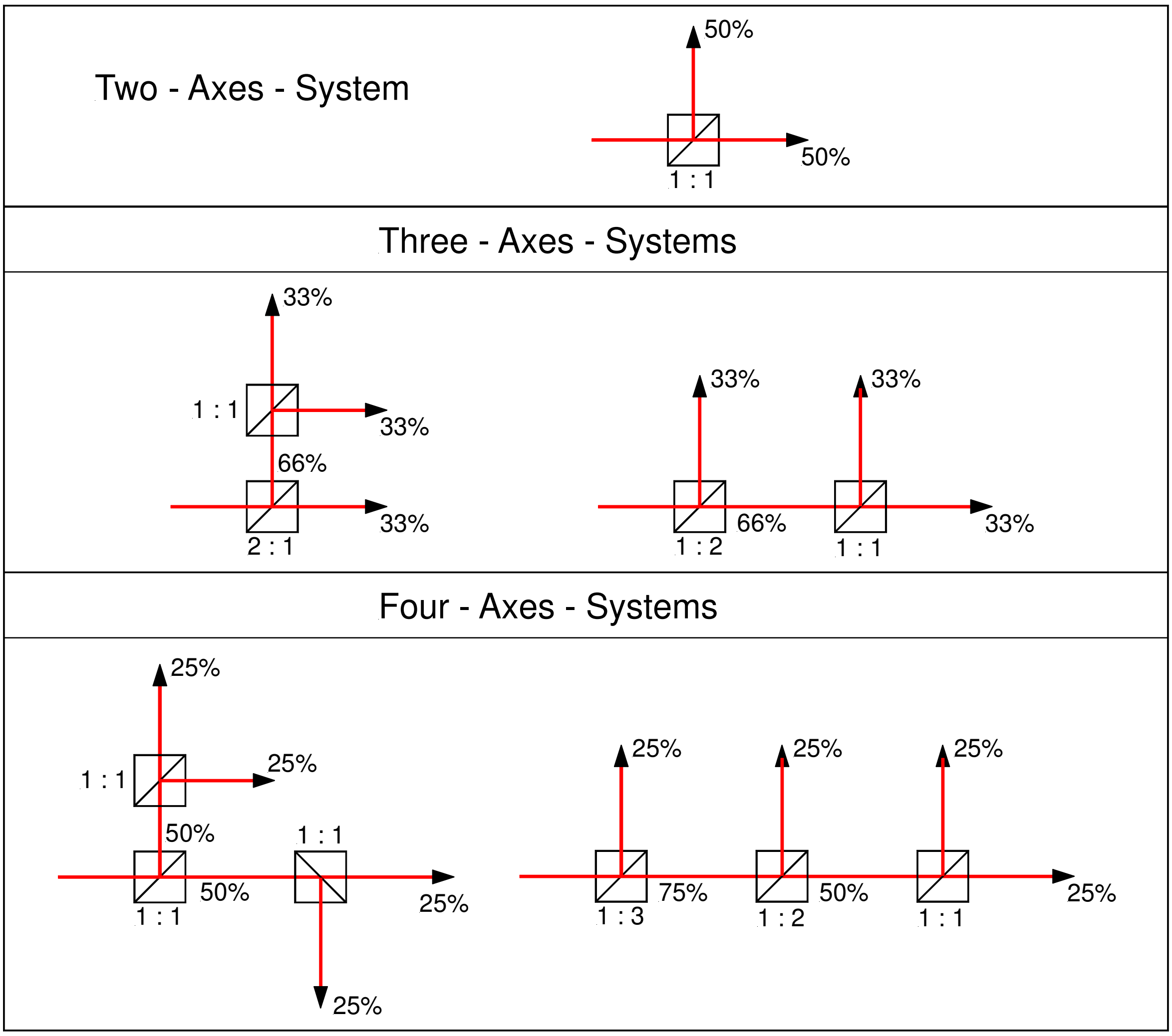


Fig. 27: Example of possible variants of beam splitting in multi-axis systems

2. **The overlap** of the measurement and reference beams:
   It is essential for each axis: The reflected beams are brought to interference and analysed. Therefore, both beams are brought to overlap (Fig. 28, 29)
   The quality of this overlap is for the signal formation in the electronic evaluation unit very importance. (The measurement signal is produced only from the area of overlap of the measurement and reference beams. The optical interference takes place only at the region of overlap of the two beams. The nonoverlapping areas generate a signal which contains no measurement information.) A good practice to observe the overlap at the fibre optic coupling of the two beams is to watch the spot on an white paper strip. The coincidence between the measurement and reference beam can be recognized by alternately covering of the measurement beam path and comparison with the reference beam. The total optical power at the interferometer must be at least **20µW**. Of these, **50% from the reference channel and 50% of the measured channel**.

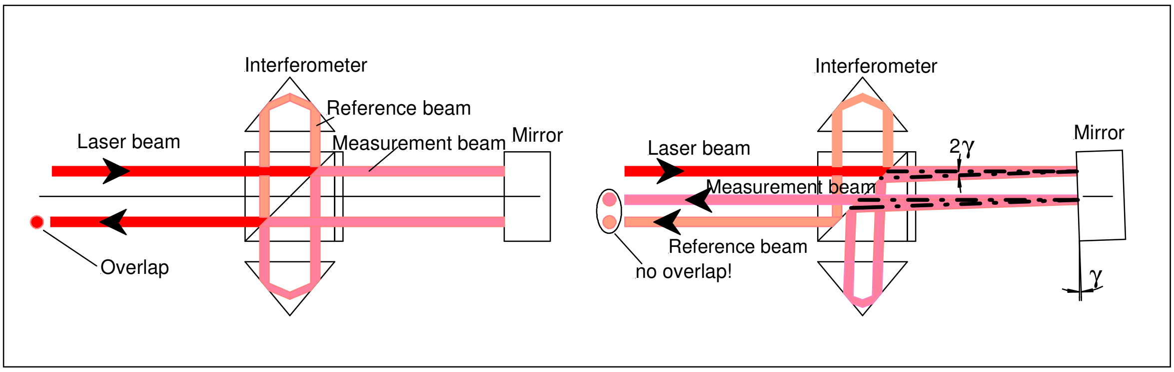


Fig. 28: Overlap of measurement and reference beam

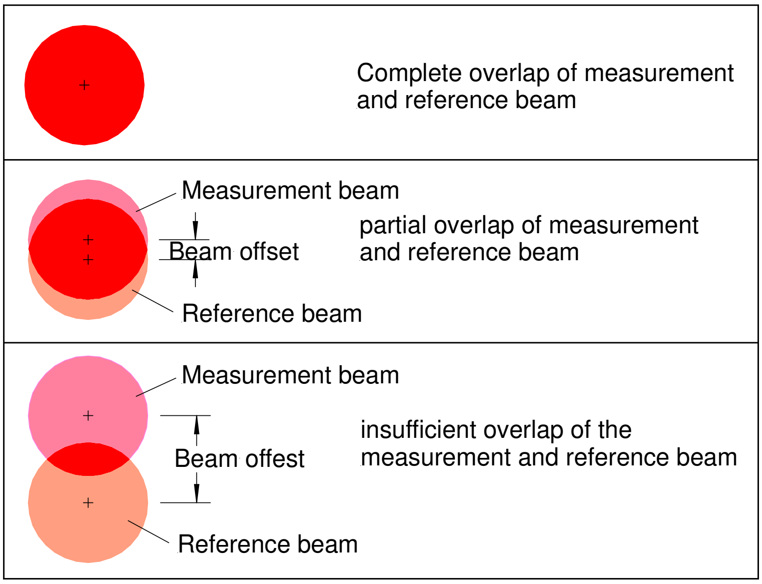


Fig. 29: Quality of the overlap

Ideal case!

In case of small offsets (up to 20%), the function is still guaranteed.

No function!

Bottom right of the screen goes red: "no light signal".

Evaluation unit: LED light signal indicator is red.

3. The corresponding **laser beam** must be adjusted in **parallel** to the **axis of motion of the displacement** being measured (in each axis!).
   If using of plane mirrors as reflectors, they are aligned perpendicular to the laser.
   Cosine error is a measurement error caused by an angular misalignment between the measurement beam and the axis of motion of the displacement being measured.
   Lateral misalignment will result in an offset which does not vary with displacement of the measurement mirror.
   Angular misalignment will result in an offset which varies with the displacement of the measurement mirror.
   Because the displacement of the reflector (more precisely: its centrally symmetric point) with the machine along its axial direction, the laser distance measurement x_L appears smaller than the displacement x_M.
   It is the context:

$$x_L = x_M \;.\; \Delta\rho \quad (< x_M)$$

   The resulting "cosine error" is derived from it as an approximation and the error second order:

$$\Delta x_{cos} = x_L - x_M = x_M \;.\; \Delta\rho^2/2$$

   The following table 2 shows for different alignment Δρ (in arcsec or mrad)
   an overview of the misalignment (in mm/m) and the two resulting effects.
   These are the measurement error Δx/x and the beam offset V for the returning beam relative to its ideal direction.
   For example, a deviation of the parallelism of the axes from 0.5mm/m generated a relative measurement error of $\Delta X/X = 0.12 \;.\; 10^{-6} = 0.12 \mu m/m$. The resulting beam offset V of 1mm/m of measurement path can create problems with the signal formation if there is a larger displacement of measurement mirror. One measurement may no more be possible. (Fig. 28)

angular deviations Δρ		corresponding alignment error	resulting effects	
			measurement error	beam offset V
"	mrad	mm/m	Δx/x	mm/m
412	2	2	$-2 \cdot 10^{-6}$	4
206	1	1	$-0{,}5 \cdot 10^{-6}$	2
103	0,5	0,5	$-0{,}12 \cdot 10^{-6}$	1
21	0,1	0,1	$-0{,}005 \cdot 10^{-6}$	0,2
10	0,05	0,05	$-0{,}001 \cdot 10^{-6}$	0,1

Table 2: Effects of misalignment on measurement error ("cosine error")

Comparator error: According to the Abbe's principle should be the laser measurement beam x_L in alignment with the test machine axis x_M.
But in many applications this is not practical. By tilting the guides a comparator error is generated. This is a first-order error. For example, an angular difference of Δρ = 5 " between the measured positions x1 and x2 and a parallel distance of 100 mm results in a length error of 2.5 microns.

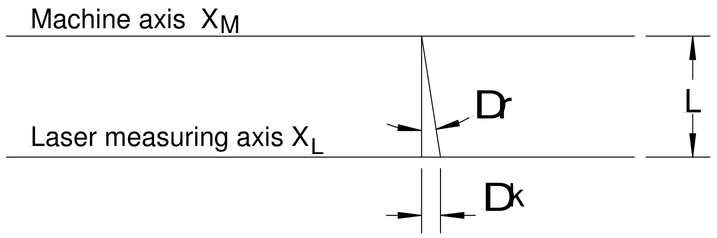


Fig. 22 shows a measurement assembly of a machine.
For the correction of the comparator error are measured position, pitch angle and yaw angle in one axis direction simultaneous.

4. The **polarization of the laser beam** must be considered with the arrangement and adjustment of the single optical construction elements. The laser beam consists of two modes F1 and F2, which are polarized perpendicular to one another. They form a "polarization cross" whose relation plane is the laser head mounting surface. F1 is the vertically polarized mode and F2 is the horizontally polarized mode with respect to the laser head mounting surface.
   The laser head may be mounted on any plane, as long as it is aligned with one of the polarizations perpendicular or parallel to the axes of measurement.
   In the design of multi-axis systems with beam distribution and beam benders is to ensure that no occur rotations of the polarization directions to the installation position of the interferometer. If the interferometer is rotated to the "polarization cross", there is not an exact separation of the modes F1 and F2. A small part of frequency F1 is mixed with F2 and vice versa.

   This results:

   $$F1 - \Delta F1 + \Delta F2 \quad \text{and} \quad F2 - \Delta F2 + \Delta F1$$

   on the two channels F1 and F2, (measuring and reference channel), Fig. 30. The accuracy of the measurement will be affected.
   A misalignment of the laser or interferometer about the optical axis will significantly increase interfering parts of the other frequency.
   This mixing of the modes results in signal deterioration up to the loss of function.
   For small rotation angles, the overlapped light intensities are very low. (Table 3).

   $$\Delta I_{F1} = I_{F1} - I_{F1} \cdot \cos^2\Delta\varphi \quad \text{and} \quad \Delta I_{F2} = I_{F2} - I_{F2} \cdot \cos^2\Delta\varphi$$

Rotation of the polarization cross Δφ	15’	30’	45’	1°	1°30’	2°
overlapped light intensities	0,0014%	0,014%	0,034%	0,06%	0,14%	0,24%

Table 3: Percentage of overlapped light intensities in case of rotation of the “polarization cross“.

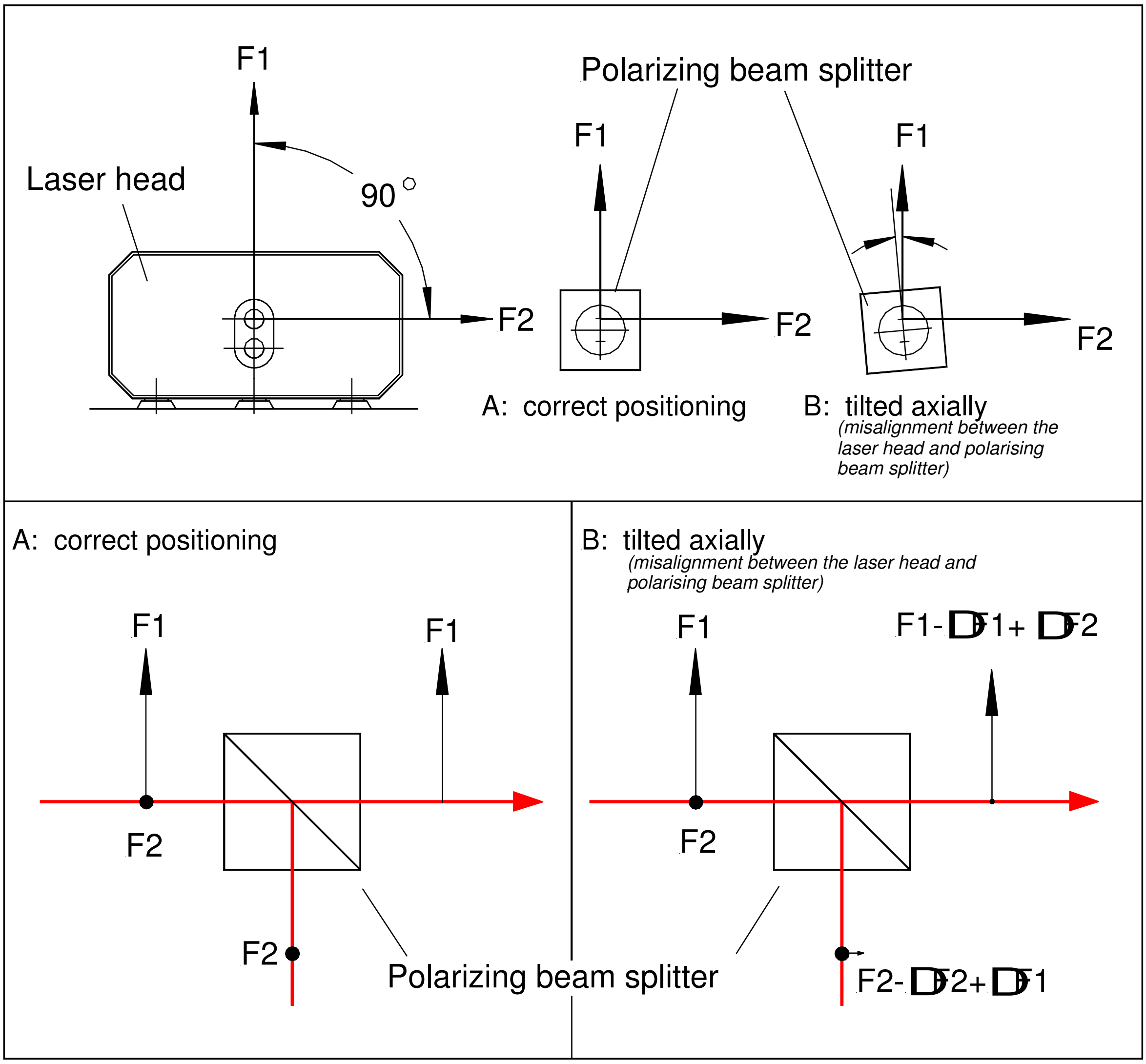


Fig. 30: Mixing of modes by rotation of the interferometer to "polarization cross "

Note:
In the design of multi-axis systems care must be taken that the laser beam from the laser head should guided to the optical modules within a level or multiple levels always at right angles. Slanted direction of optical assemblies can lead to rotation and distortion of the polarization cross.

The parallelism of the optical modules to the supporting surface of the laser measuring head should be:

$$\Delta\varphi \leq 30' \quad .$$

3.2. Different variants for the mounting and adjustment of the optical modules

By means of the mounts 588, 589 and 590 (see page I-10, fig.s 19-21) the optical modules can be adjusted in two axes.
Figures 31 and 32 show various mounting variants and the position of the aligning planes for use with beam guidance modules (fig. 32 and fig. 33 show the use with interferometers).

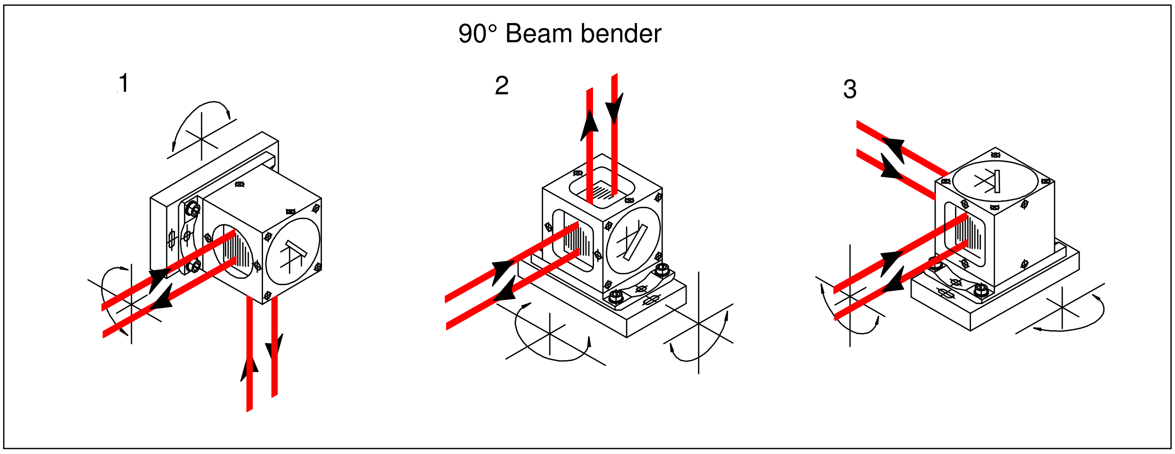


Fig. 31: Installation and adjustment possibilities of modules size A (□ 40) for beam guidance

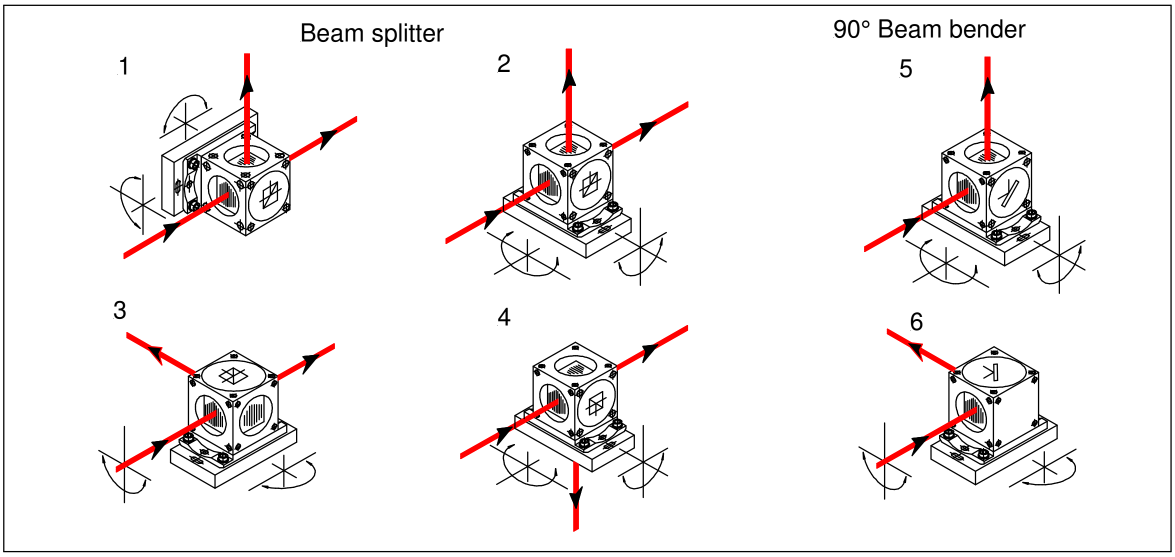
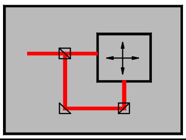


Fig. 32: Installation and adjustment possibilities of modules size B (□28, □20) for beam guidance



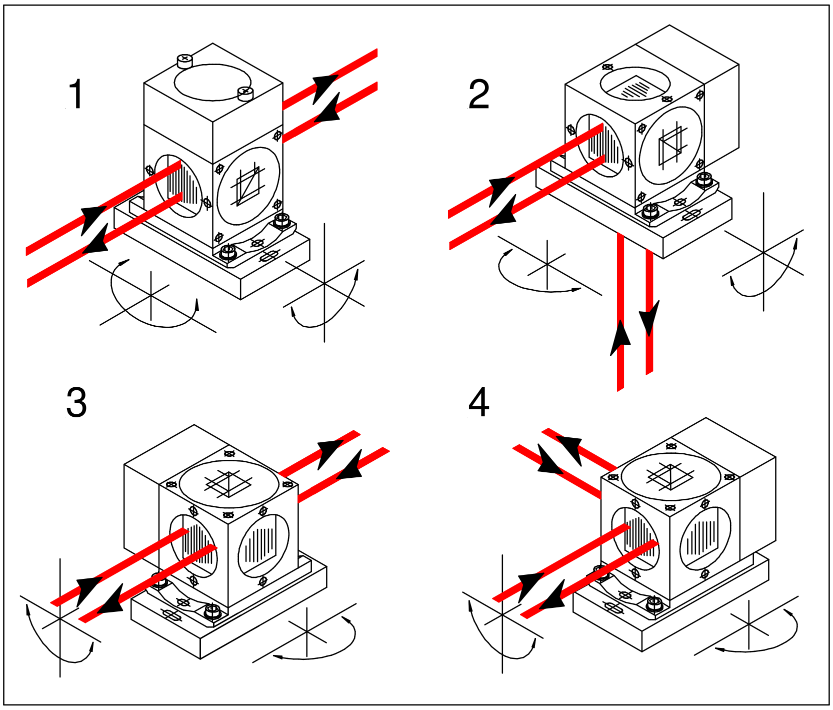


Fig. 33:
Installation and adjustment possibilities of interferometer with cube corner reflector:

- Adjustable mount 588
- Polarizing beam splitter 101
- Cube corner reflector 102

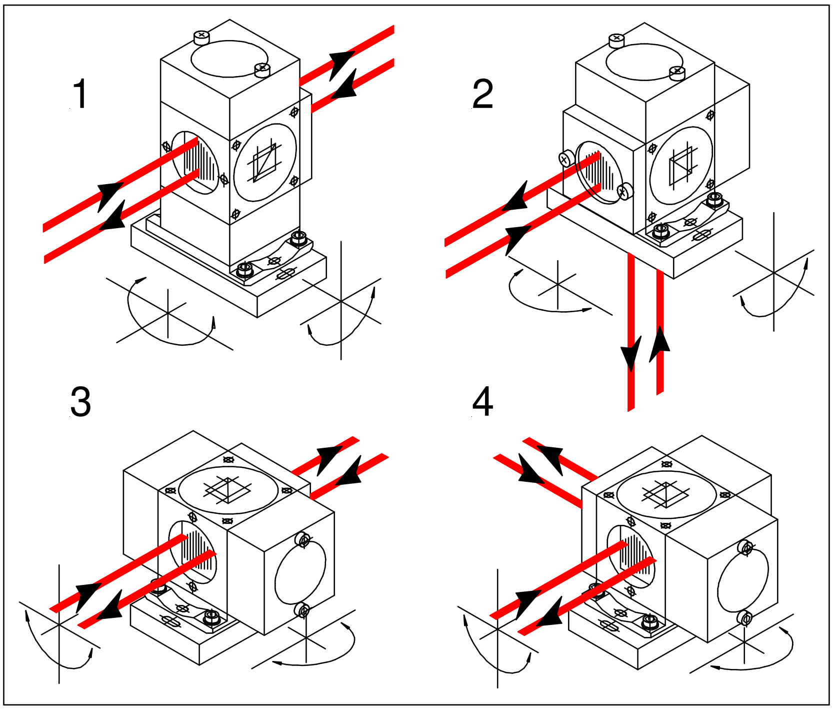


Fig. 34:
Installation and adjustment possibilities of plane mirror interferometer:

- Adjustable mount 588
- Polarizing beam splitter 101
- 2x Cube corner reflector 102
- λ/4 Plate 104

3.3. Description of the mounting and adjustment procedure

3.3.1. Description of the two-axis system using the example of Figure 1

The measurement setup consists of an XY-stage, which consists of two superimposed and perpendicular to each other arranged guides. On the XY-stage are two mirrors are mounted perpendicular to each other. The mirror are the same height. The length of the mirror is equal to the length of the guides.

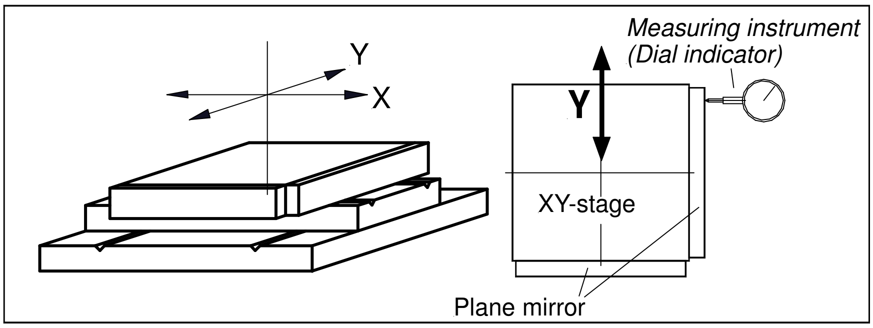
The measuring system consists of two interferometers, one for the x-axis and one for the Y-axis.
The output beam of the laser head is splitted by the 1:1 Beam splitter into two beams.
These are passed over two 90 °Beam bender to the interferometers.
The two plane mirrors at the XY-stage are used as measuring reflectors.
As reference reflectors are used cube corner reflectors which are fixed to the respective interferometer.
(This interferometer is described in Section B plane mirror interferometer page B-1 as the 2nd variant.)

The returning laser light is coupled out of the interferometer via optical fibres (LWL). The optical fibres are inserted into the fibre-optic couplings to the interferometer and connected with the evaluation unit.
The reference optical fibre comes from the laser measuring head directly.

3.3.2. Assembly and Alignment procedure of the two-axis system

Assembly and optical alignment is best performed in a series of separate, consecutive individual steps. These individual procedures are described in detail over the succeeding pages. Perform the procedures required for your particular application. The recommended individual steps are:

<u>first step</u>*:*
Position the plane mirrors on the stage

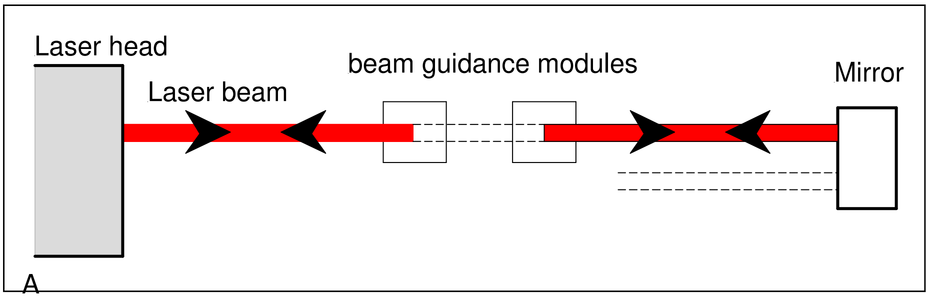


A

Fig. 35: XY-stage with plane mirror reflectors

The first step is the two plane mirrors (target mirrors) as accurately as possible perpendicular to align the axes of movement of the XY-stage. Here may be applied mechanical or non-contact measuring instruments (e.g. Dial indicator). Be careful: Not scratch the coated surface of the mirror when using the mechanical measuring instrument! Carefully position the dial indicator tip on the mirror surface outside the clear aperture. (XY-stages with mirrors that are not adjustable, must be produced in advance with sufficient accuracy.) Ensure that the beam is aligned over the full range of travel.

<u>second step:</u>
Alignment of the beam guidance modules



A
F

Fig. 36: Laser measuring head - Beam guidance modules - Mirror

First, the laser head and the beam-guiding optics modules, 1:1 Beam splitter and 90 °Beam bender, are mounted (see fig. 37a).

- ***For measurement system set-up: please respect for the constructive dimensions of the beam guidance modules. (e.g. height of beam passage)***
- ***The supporting surfaces of the laser measuring head and the optical modules must be parallel to each other. (Check using spirit level, inclinometer)***
- ***The points of laser light on the optical components must lie in the same plane (in Fig 37a marked with "1, 2, 3, 4 and 5").***

Alignment procedure: The position of the points of laser light 1 to 5 are determined in the same basic height by laser pinholes (Fig. 38). Through the pinhole, the laser beam must run centrally.
If there are differences by the base level of the position of the points of laser light, the pinhole distances must be adjustable to the appropriate height.
Alignment of the beam heights:

- The same beam height between position of laser pinhole "1" and "3" is achieved by tilting the laser measuring head.
- The same beam height between position of laser pinhole "1" and "2" is achieved by tilting the 1:1 Beam splitter.
- The same beam height between position of laser pinhole "3" and "4" is achieved by tilting the 90 ° Beam bender "3".
- The same beam height between position of laser pinhole "4" and "5" is achieved by tilting the 90 ° Beam bender "4".

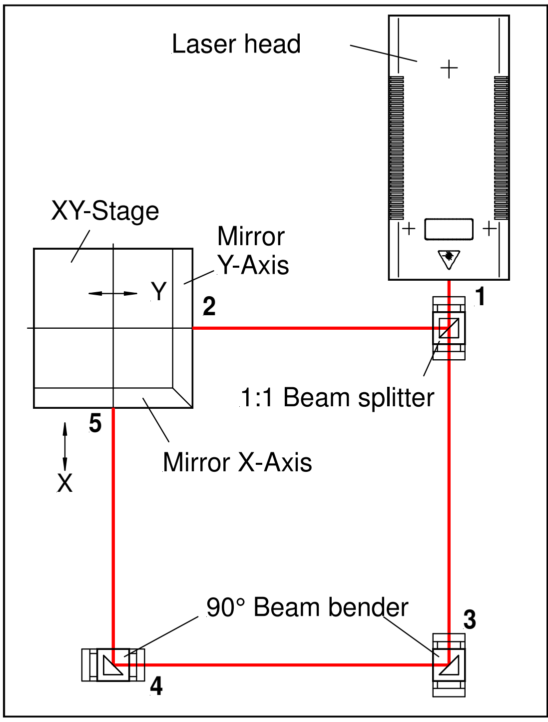


Fig. 37a

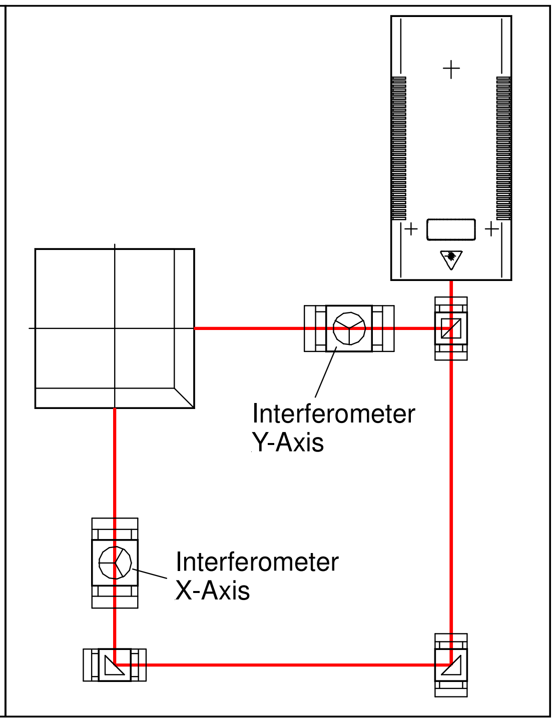


Fig. 37b

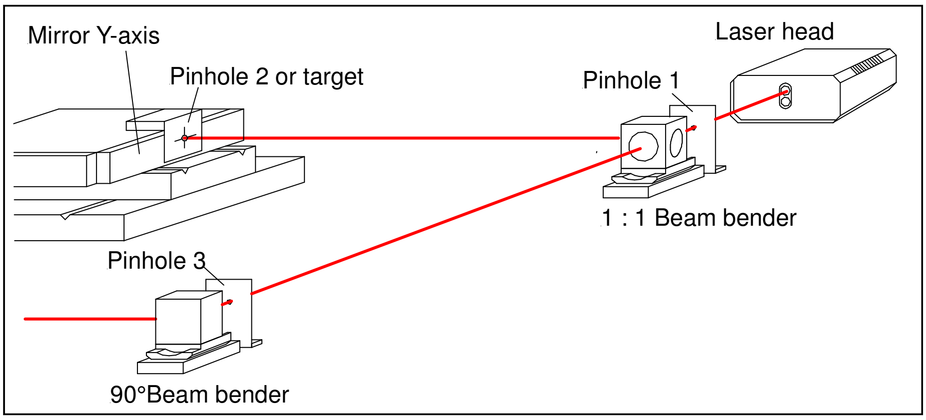


Fig. 38 Alignment of the beam heights by using pinholes

- ***The beam path directions between the 1:1 splitter and the mirror of the Y-axis as well as between 90° Beam bender (3) and the mirror of the X-axis must be parallel to the directions of movement.***

Alignment procedure: (Fig. 37)
Begin the alignment with the optical component nearest to the Laser head and work outward.
So at first, the 1:1 Beam splitter is aligned to the Y-axis (covering the X-axis plane mirror).

– Attached a target (e.g. a piece of paper with crossline) on plane mirror where laser beam should be later (Fig. 38).
– Move the XY-stage to the rear end position (long distance)
– Align the laser beam on the target by adjusting the mount of the 1:1 splitter.
– Move the XY-stage to the front end position (short distance), thereby observe the laser spot on the target
– Is there a deflection of the laser spot Δm, the 1:1 splitter must be readjusted (Fig. 39).

Tip:

This adjustment can only gradually approximately (iterative) be done. It should alternately tilting and parallel displacement in each case at half the amount of the deviation be performed.

- ➢ In the front end position (short distance): parallel displacement
- ➢ in the rear end position (long distance): tilting

If is no more visible displacement of the target mark (Δm=0), the setting of the 1:1 Beam splitter to the Y-axis is finished. It is fixed in this position.

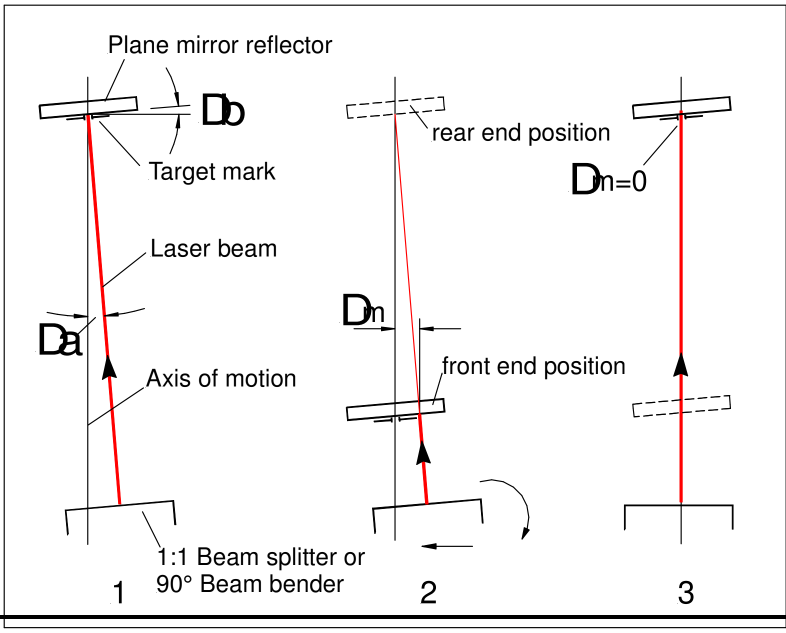


Fig. 39:
Adjusting the beam direction of the laser beam to the movement direction of the axes of the XY-stage

(Compensate for the lateral displacements of the reflected laser beam (yaw of the plane mirror))

Next follows the alignment of the X-axis:

- Attached a target (e.g. a piece of paper with crossline) on plane mirror where laser beam should be later.
- The two 90°Beam bender has been already set in the beam height. They are so assembled that the laser beam centered in the lateral direction.
- The further adjustment is made with 90°Beam bender "4". The procedure is the same like at the Y-axis, except that adjusted with the 90°Beam bender "4".

If is no more visible displacement of the target mark ($\Delta m=0$), the setting of the 90°Beam bender to the Y-axis is finished. It is fixed in this position.

If the plane mirror reflectors tilted to the axes of motion ($\Delta\beta$) then the reflected beams are deflected by $2\Delta\beta$. (see fig. 40) Compensate for the vertical displacements of the reflected laser beam (pitch of the plane mirror)

- ***The reflected laser beams from the plane mirror reflectors have to run back into itself.***

Alignment procedure: In front the laser head is mounted a pinhole, centric to the out-going laser beam. (see fig. 38). The target marks of the plane mirrors (x and y) are removed.
The position of the laser spot (reflected from the plane mirror to the back of the pinhole) must be observed now. It is advisable to cover the other beam.
Between front and rear end position there is a displacement of the laser beam from Δn. Be achieved by tilting the plane mirror by $\Delta\beta$ that the reflected beam again passes centrally through the pinhole. Thereby the displacement of $\Delta n = 0$ is set (fig. 40).

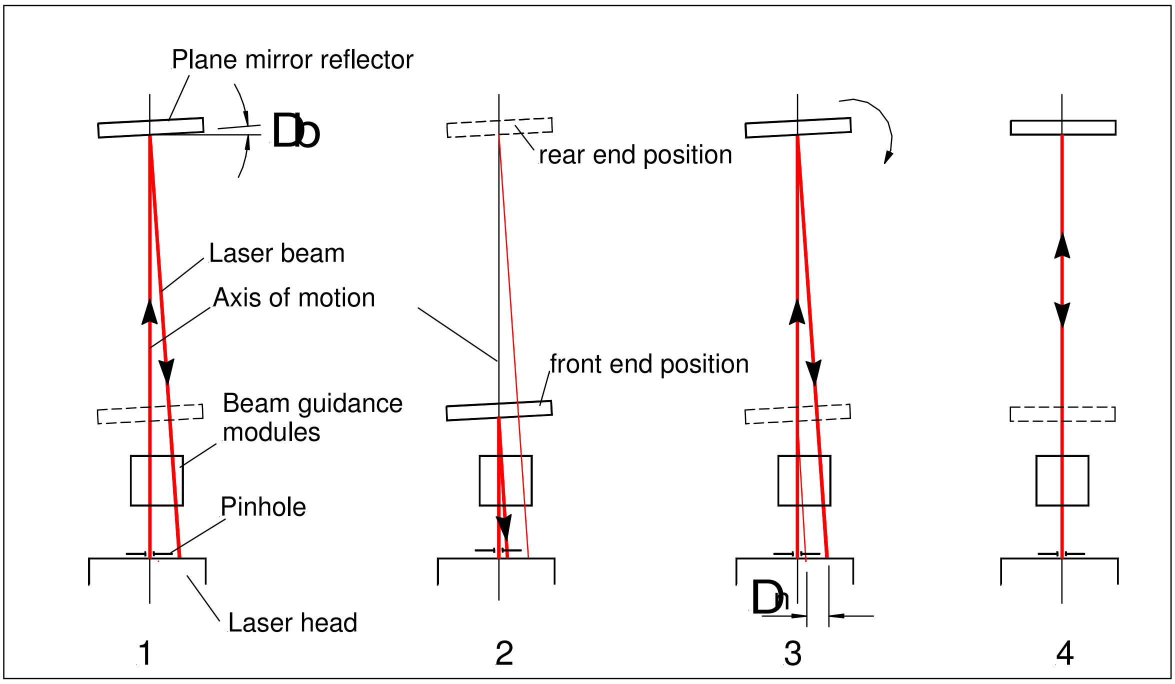


Fig. 40: Adjustment of the plane mirror reflector to the motion axis

For XY-stages with plane mirror reflectors which are not adjustable, when producing it is necessary to keep the error $\Delta\beta$ as low as possible. After adjusting of the parallelism of the laser beam to the movement axis and if precise production of the XY-stage with mirrors is guaranteed, the laser beam is reflected in itself exactly. If this is not reached, it must be readjusted at the expense of parallelism.

Important!	The priority is in each case the adjustment of the reflected beam $\Delta n = 0$. The adjustment of the parallelism is secondary.

The reflected beam is essential for the overlap. (see Chapter 3.1. point 2, page I-16).
The deviation from parallelism leads to the "cosine error". (see Chapter 3.1. point 3, page I-17).

<u>third step:</u>
Adjustment of the interferometer

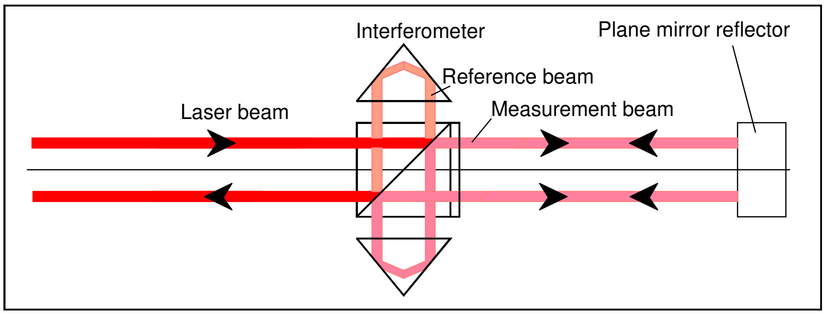


Fig. 41: Plane mirror interferometer

At first it is appropriate to mount the interferometer without fibre-optic couplings, because the returning laser beam can be better assessed. Instead of the fibre-optic coupling a diaphragm is mounted.
With its help the interferometer is to be moved in the right position . The returning beam can be observed at the interferometer using a paper strip.

The fault tolerance of the interferometer can lead to a partial loss of the adjustment accuracies (achieved in "second step"). Therefore, a fine adjustment is to made.

Fine adjustment:

- Repeating the adjustment of the parallelism of the laser beam to the movement axis
  The procedure is to performed exactly as described in the **"second step "**.

- Repeating the adjustment of the reflected laser beam
  As a assessment criterion of the reflected beam is used the overlap at the interferometer. Otherwise, proceed as described in the **"second step "**.

  Measuring and reference beam must overlap each other in the complete measuring range between the front and rear end position. (see Chapter 3.1. point 2, page I-16)

Warning! Back-coupling!

For absolutely accurate adjustment can lead to back coupling.
This means that reflected light passes back into the laser tube and disturbs the control of the wavelength stability. (LED-green at the laser head flickers or is changed to red.)
To remedy: The laser beam must be misaligned a little bit from the ideal position.

<u>Fourth Step:</u>
adjustment of the Fibre optic coupling

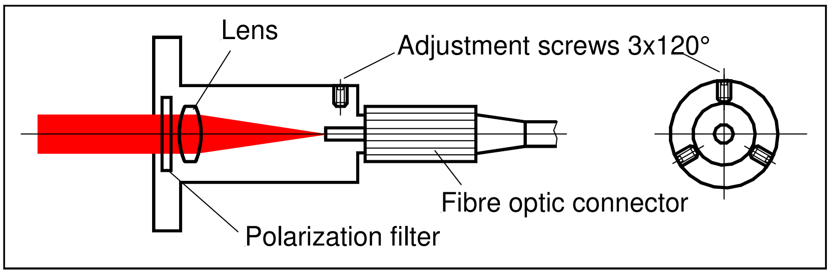


Fig. 42: Fibre optic coupling with adjustment screws

The fibre optics coupling is mounted to the interferometer. The fibre-optic cable (FOC) is screwed.
The adjusting screws are each offset by 120° to each other. Thereby the connector of the fibre optic cable to the focal point of the laser beam is moved. The laser light output is checked at the other end of the fibre. This can be done with a laser power meter or visually.

Warning!

Do not look into the laser beam!

For visual control is inspected the projection of the outgoing laser beam on a white sheet of paper. The projection should be an uniformly illuminated spot and have maximum brightness.
The adjustment is finished, if:
- the maximum of the light output is reached
- after alternate covering of measuring beam and reference beam the light power have equal proportions (50%)
- uniform illumination is present.

The sum of the light output should be at least **20µW**.

The adjustment is finished and the system can be put into operation.

Summary overview of the calibration steps

First step	
Description	**Results**
Assembly and adjustment of the plane mirror reflectors on the XY-stage	The plane mirror axes must be positioned at right angles to the axes of movement of the guideways exactly.
Second step	
Mounting and adjustment of the laser measuring head and the beam guidance modules	The laser beam must be to the axes of movement of the guideways parallelly . The incident laser beam must be at the plane mirror reflectors perpendicularly.
Third step	
Mounting and adjustment of the interferometer	Measuring and reference beam must overlapped each other. There should be no back-coupling.
Fourth step	
Mounting and adjustment of the fibre optic couplings.	At the output of the optical fibre there must be the maximum of the light output.