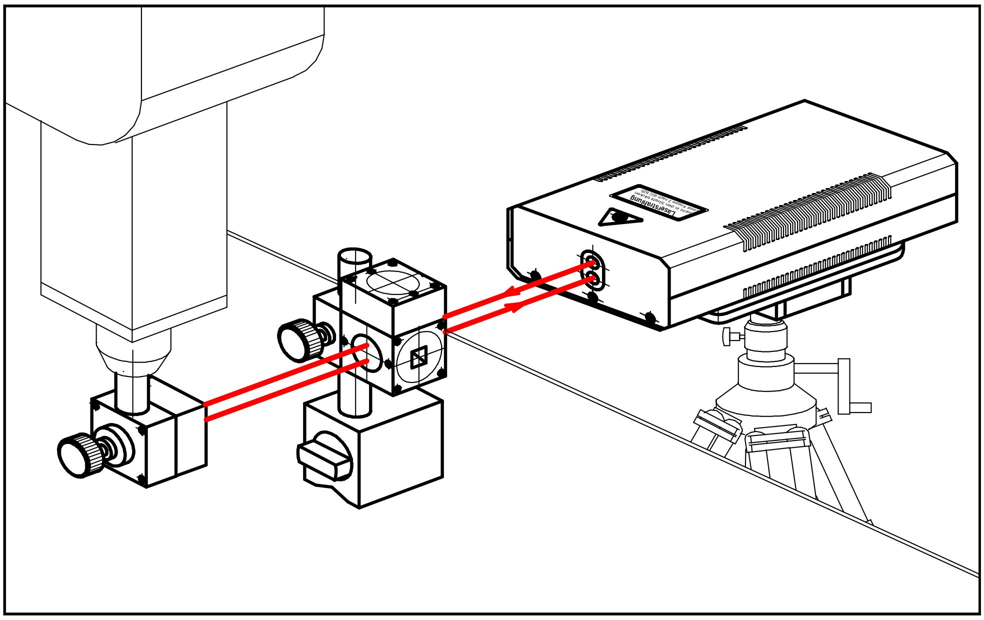
Dual-Frequency Laser Interferometer

ZLM 700
ZLM 800

Manual on the

Basic Equipment for the Measurement of Translatory and Rotatory Quantities

(Corner Reflector, Plane Mirror and Angle Interferometers)



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The equipment described in this manual is subject to technical upgrading and other changes without prior notice.

Familiarity with the contents of this manual is imperative for safe operation of your equipment. Therefore study the manual thoroughly before starting up the equipment.

Keep this manual and any other user documentation supplied within reach of the operator.

Modifications and repairs of the equipment may not be carried out by persons other than our own service staff or competent engineers expressly authorized by us.

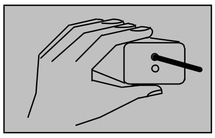
The ZLM 700/800 Laser Interferometer is guaranteed by the seller for a period of 24 months from the date of delivery.

The seller expressly disclaims any responsibility for damage to equipment and/or persons which should result from improper use, failure to observe the operating instructions, faulty or negligent handling or natural wear.

Furthermore, the purchase of the equipment is subject to the General Conditions of Sale of JENAer Meßtechnik GmbH.

ZLM 700 / 800 - Table of Contents

optics
by Carl Zeiss



1. Safety notes

Generally notes

Please study the manual thoroughly before starting up the equipment! Additionally information you can get by our service!

> Please pay attention to the warnings and hints in this manual!

1.1. Notes on handling HeNe-Gas Lasers

The He-Ne gas laser used in the ZLM is powered by DC from the equipment's power supply unit. Mind the safety precautions common for electrical equipment:

1. Connect the laser to a properly grounded mains socket outlet only.
2. Do not operate the He-Ne laser when the enclosures of laser head and/or power supply unit are open.

The laser used in the ZLM 700 / 800 is a class 2 laser acc. to DIN EN 60 825-1 edition 11/2001. No safety goggles are needed, since the low-power radiation (max. 1 mW) is harmless to human eyes. (The eyelid closure reflex protects your eyes against the direct laser beam). There is no fire hazard.
The Laser Interferometer may only be switched on, operated and adjusted by persons who have been authorised to do so and can be proved to have received through instructions on handling and operation.

Warning !

Do not leave the Laser Interferometer in unattended operation. Mind the following recommendations:

- Arrange your setup so as not to have the laser beam at eye level.
- Avoid looking into the direct or reflected beam.
- Do not look at the laser beam with optical aids not belonging to the equipment, except your own eyeglasses.
- Do not direct the laser beam at persons.
- Avoid accidental reflections.

DANGER ! LASER RADIATION !

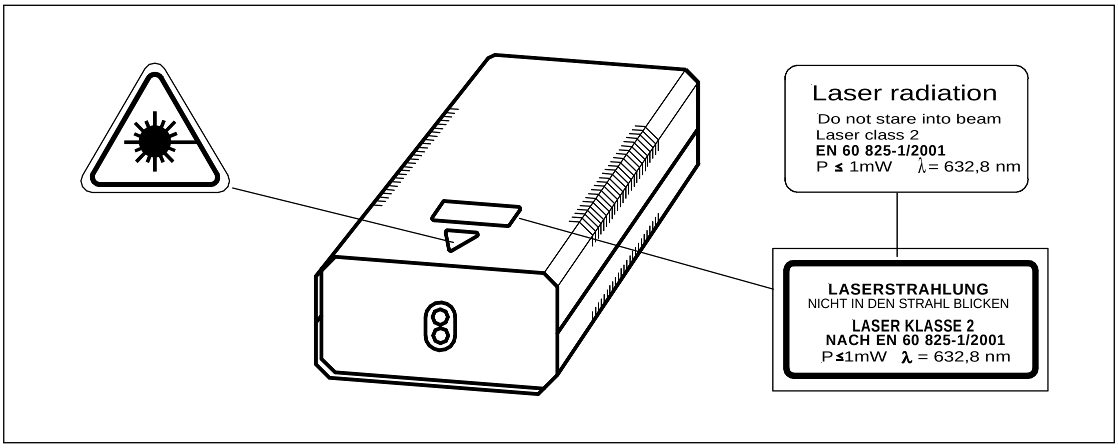
NEVER LOOK INTO THE LASER BEAM,
NOT EVEN WITH ANY OPTICAL AID OR INSTRUMENT !

Laser class 2

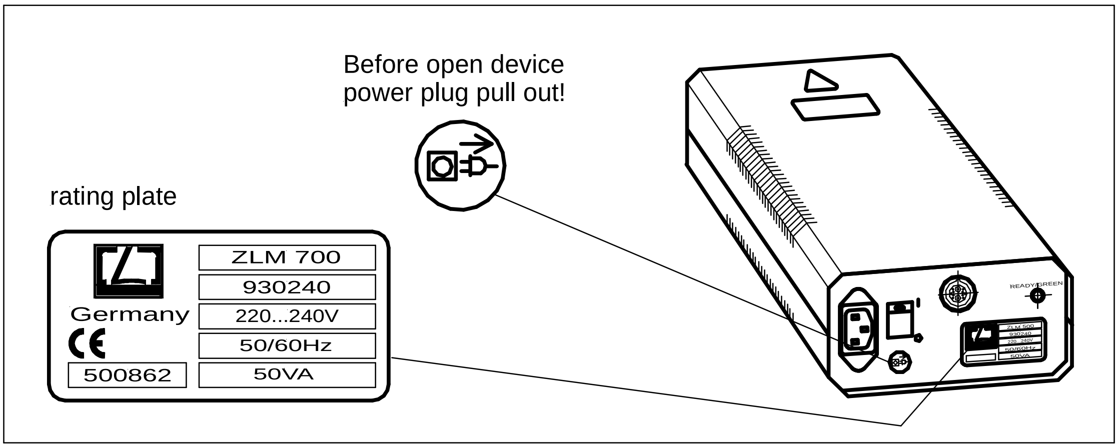
1.2. Instruction and Warning Labels

1.2.1. European standard / 220 Volt

Label on top of laser head

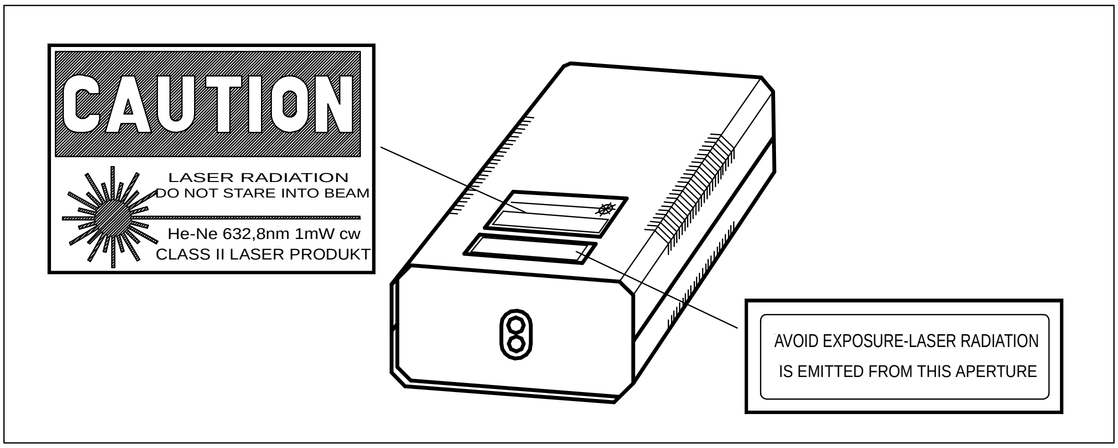


Rating plate and other labels on rear end of laser head

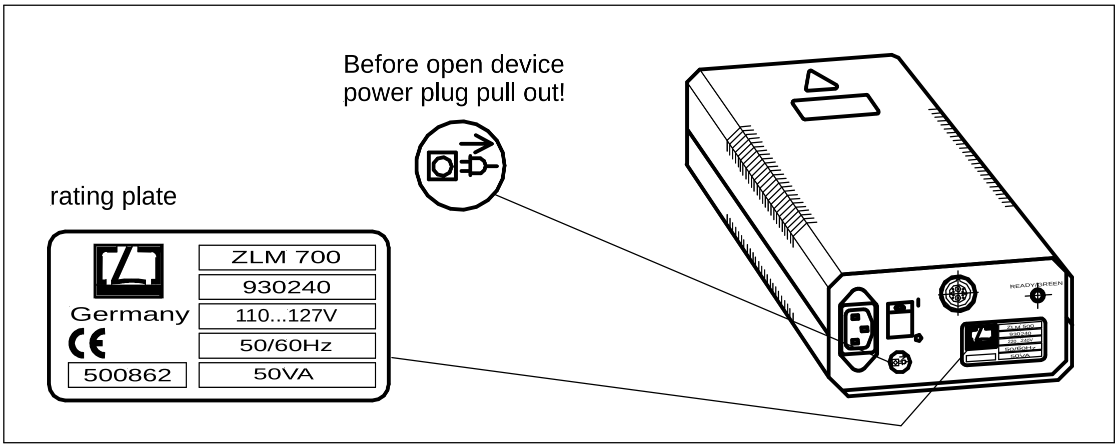


1.2.2. American standard / 110 Volt

Label on top of laser head



Rating plate and other labels on rear end of laser head



1.3. Notes for electromagnetic compatibility EMI

The measuring unit system corresponds to the regulations of the law over technical terms (Equipment safety law).
The measuring system satisfies the safety regulations for electrical measuring – steering – regulation and laboratory - equipment IEC 1010 – 1.
Electromagnetic compatibility EMI examination was proving:

- The radio interference suppression fulfills the requests EN 55011 class A

- The interference immunity fulfills the requests EN 50082 - 2

To get this condition, this has to be use for the measuring unit system only as agreed. Please following notes and warnings.

The gauge is EG – concurring and is having CE – symbol

Low voltage 73/23/EWG
EMV 89/336/EWG

1.4. Indications for transportation and storage

The measuring system ZLM 700 / 800 is delivered in corresponding storage and transportation cases (chapters “Assembly of modules and components” P 4-7). It is advisable, these to use permanently for storage and further. This way the equipment components are protected. At the transportation intense pushes have to be avoided.
The range of temperature for transport and storage should not be oversteped: > -25℃ <75℃.
before installation the equipment must adapt to the room temperature. The measuring system works in range of temperature >10℃ <30℃.

2. Equipment description and operation

Applications

The Dual-Frequency Laser interferometer systems ZLM 700 and ZLM 800 are optical length measuring instruments which permits lengths up to 40m (optionally up to 120m) to measure with a resolution of 2.5 nm (optionally 1.25 nm or 0.63nm), at speeds of up to 4 m/s (optionally up to 16 m/s).
It moreover can determine geometric and kinematic quantities derived from length, such as speed, acceleration, angles, straightness, parallelism, squareness and flatness.
The ZLM 700/800 is conceived as a module system.

The **ZLM 700** serves mainly as a calibrating system in the tool engineering industry, coordinates measuring machines and as a laboratory equipment for different measurement tasks.
As a module system permits the ZLM700 the user to choose system components according to the requirements of the respective measurement task.

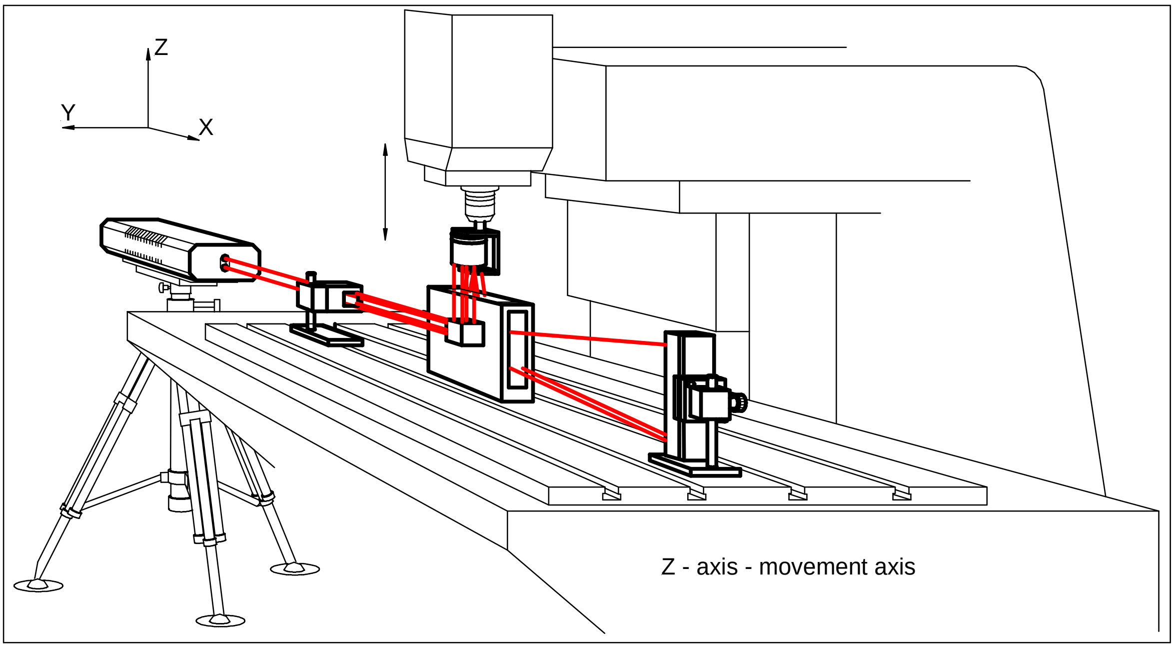


Fig. 1: Squareness measuring at a machine tool

The ZLM 700's measuring accuracy is a function of its environment (ambient temperature, atmospheric pressure and humidity, material temperatures) and the specific setup (observation of Abbe's comparator principle).

As multiaxes-system the ZLM 800 can be incorporated into fast precise positioning systems.
It serves as a dynamic system of the highest resolution for the determination of the positional deviations of the objects under measurement.
The measuring accuracy depends on the recording of the air refractive index as well as the respective constructive solution.

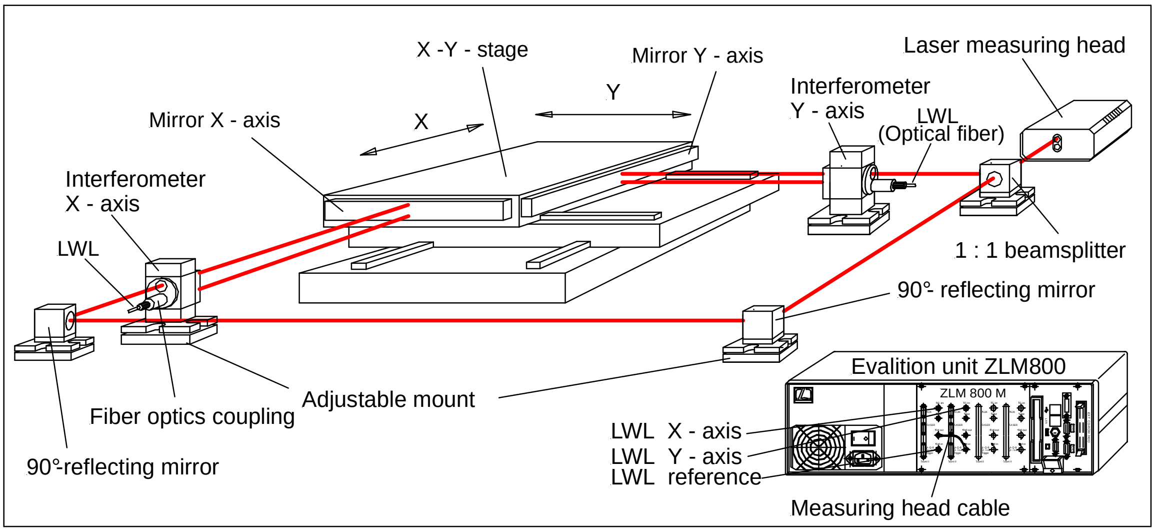


Fig. 2: Construction example: Multiaxes-system

2.1. Operating Principles

The dual-frequency laser interferometer works according to the heterodyne principle.
It comprises a laser measuring head, optical modules (to be configured by the user to suit the particular application), evaluation unit and PC (see Fig. 3). Between laser measuring head and evaluation unit make measuring head cable the electrical and optical connection.
There are 3 different variants of evaluation units:
- for notebook (and docking station) with PCI-Bus-system
- for PC with PCI-Bus-system
- for PC with PXI-Bus-system.

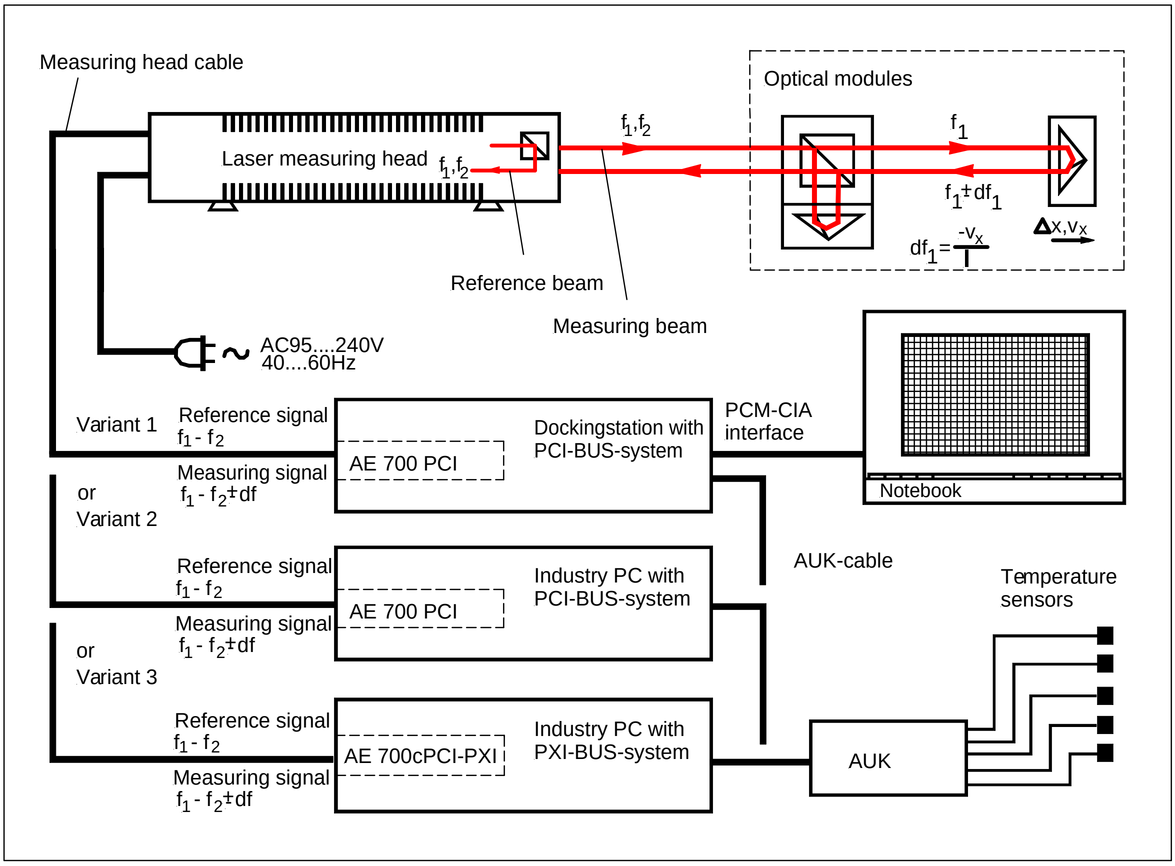


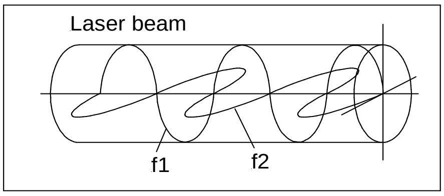
Fig. 3: The basic construction of the ZLM 700 Dual-Frequency Laser Interferometer

The frequency-stabilized He-Ne laser generates a laser beam of the Ne energy level, which consists of two oscillatory modes, polarized in mutually perpendicular planes, with the frequencies f1 and f2. The differential frequency f1 - f2 = 640 MHz.

The beam is expanded to a diameter of 6 mm by a collimator. This makes the beam suitable for measuring lengths of up to 40 m. (With different collimators AWS25/50, the useful measuring length can be extended.)

A beam splitter then branches off part of the light intensity as a reference beam, which then passes a polarizing filter whose polarization plane is at 45°. The light emerging from the polarizing filter vi brates all in the same plane, so that the silicon avalanche photodiode (detector 1) arranged behind the filter detects the beat frequency signal of f1 - f2 = 640 MHz.

Fig. 4
The polarization plane f1 be located perpendicular, the polarization plane f2 horizontal



The other portion of the light intensity forms the measuring beam. Via an interferometer arrangement assembled by the user to suit the specific measuring job, the measuring beam strikes a measuring reflector (fixed on the moving machine part) and a stationary reference reflector, from where it falls on to detector 2. Within the interferometer arrangement, the measuring beam is split up into the two frequencies by a polarizing beam splitter; as a result, the measuring reflector only receives frequency f1, whereas the reference reflector only receives frequency f2.
With the measuring reflector remaining at rest, detector 2 also detects the differential frequency of the laser light, i.e. f1 - f2 = 640 MHz. If the measuring reflector is moved, the beam portion of frequency f1 reflected by it is Doppler-shifted by ± df1. Accordingly, detector 2 now registers a Doppler-shifted differential frequency of f1 - f2 ± df1 as the measuring frequency (+df1 or -df1 depending on which way the measuring reflector is moved).

The high-frequency circuitry in the measurement sub-drawer of the ZLM 700 compares the reference frequency f1 - f2 with the measuring frequency f1 - f2 ± df1. This comparison yields the frequency shift ± df1 due to the Doppler effect; this shift is a measure of the travelling distance of the measuring reflector.

3. Laser Head with Adjusting Table and Tripod

3.1. Construction and operation

The **laser head** consists of the following modules: He-Ne laser tube, with equipment to wavelength stabilization, beam expanding collimator (for beam diameters 6 mm), laser power supply unit, 90° beam bender, beam splitter, fibre-optic cable coupler for reference and measuring beam path, adjusting unit and printed circuit board with transformer power supplies and regulator.

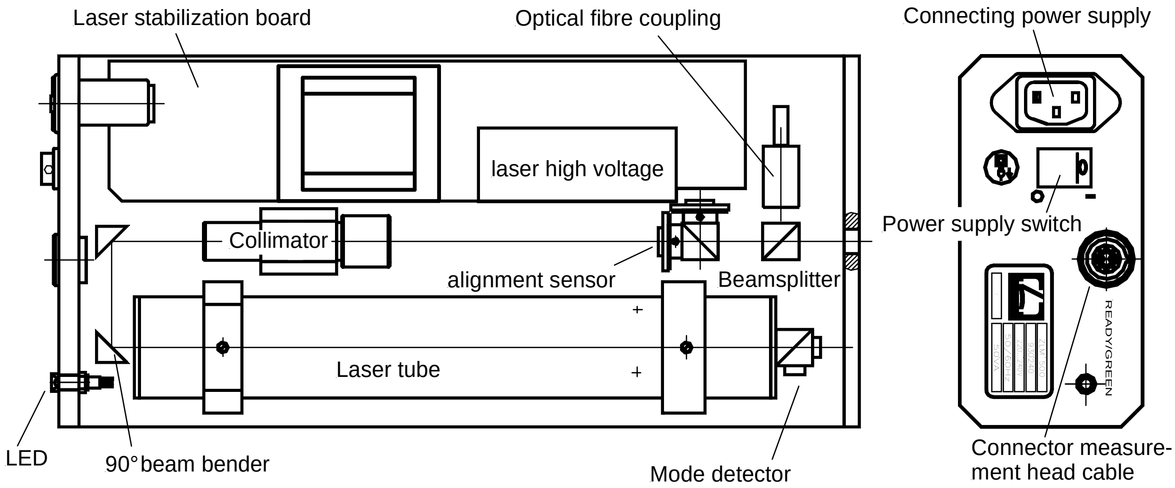


Fig. 5 : Laser head

The laser head can easily be mounted on, and demounted from, the adjusting table via the feet of the laser's base plate and the quick arrest of the table. If a different way of mounting the laser head is required, the feet may be unscrewed and suitable clamping bolts inserted instead. It is requisitely for tensionless mounting ball washer and cone washer to use (Fig. 6:).

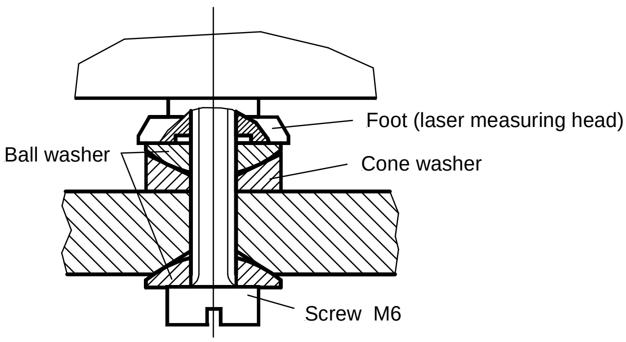
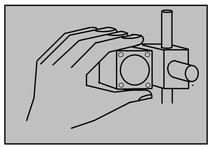


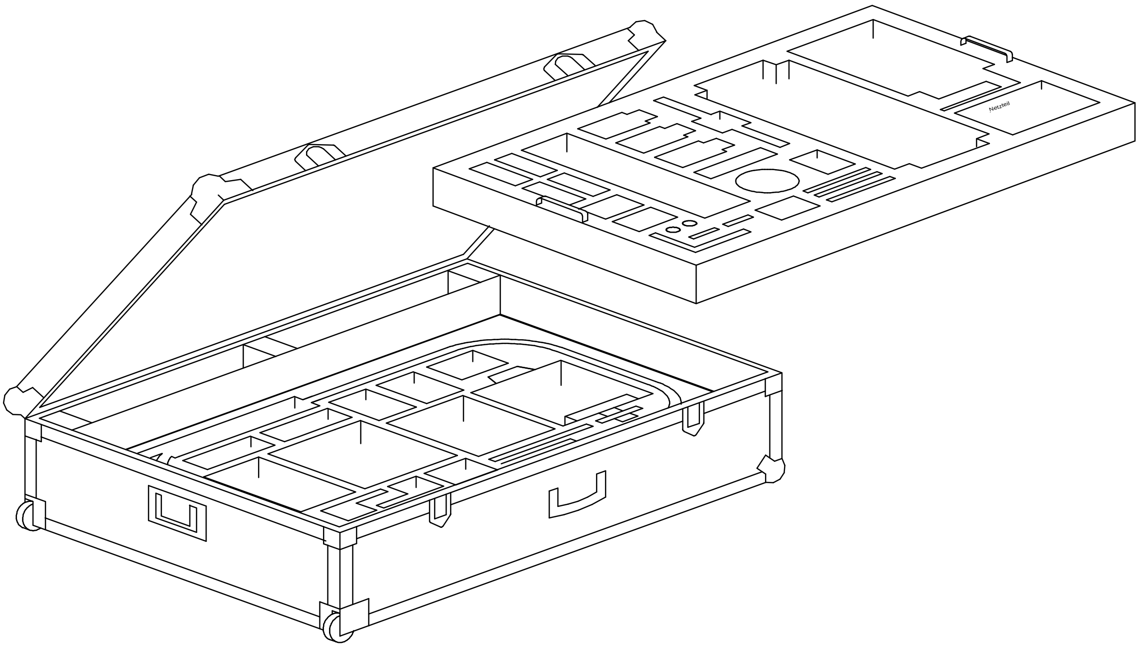
Fig. 6:
Assembling of laser Measuring head

The **adjustable table** permits the laser beam to be aligned by horizontal and vertical tilting and horizontal parallel displacement controls. Vertical parallel displacement can be effected via the adjustable column of the tripod.

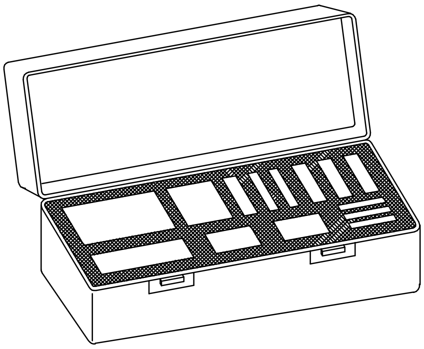
The **tripod** steadily supports the laser head in a fixed position relative to the object of measurement and to the optical modules of the interferometer. The feet can be adjusted in height for coarse alignment of the laser; vertical fine adjustment is provided by the adjustable column.



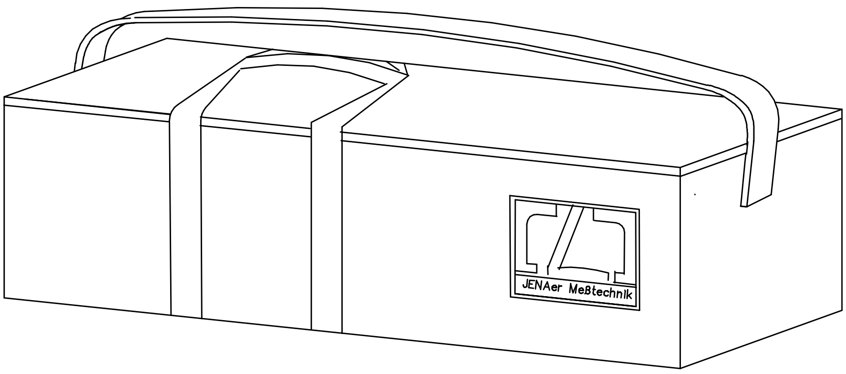
Transport case ZLM 700



Roll case with insert as a transportation and storage case for system ZLM 700



Storage container for optics modules



Carrier bag for tripod and adjustable table

Fig. 7a

Special storage containers serve for the safe storage of the extensive assortment at optics modules ***269302-4010.126***

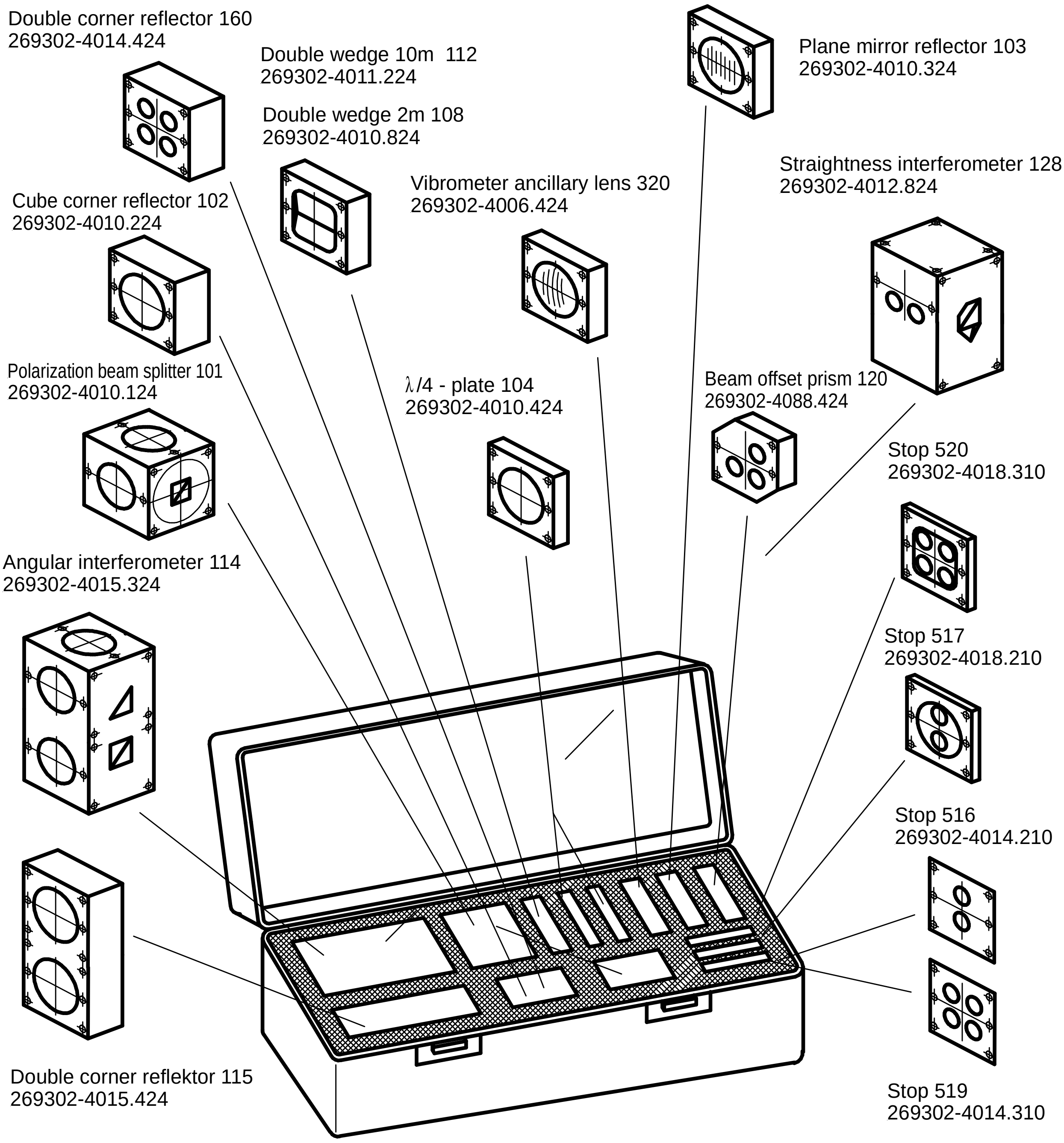


Fig. 7b: Carrying case for optics modules – arrangement of the optics modules

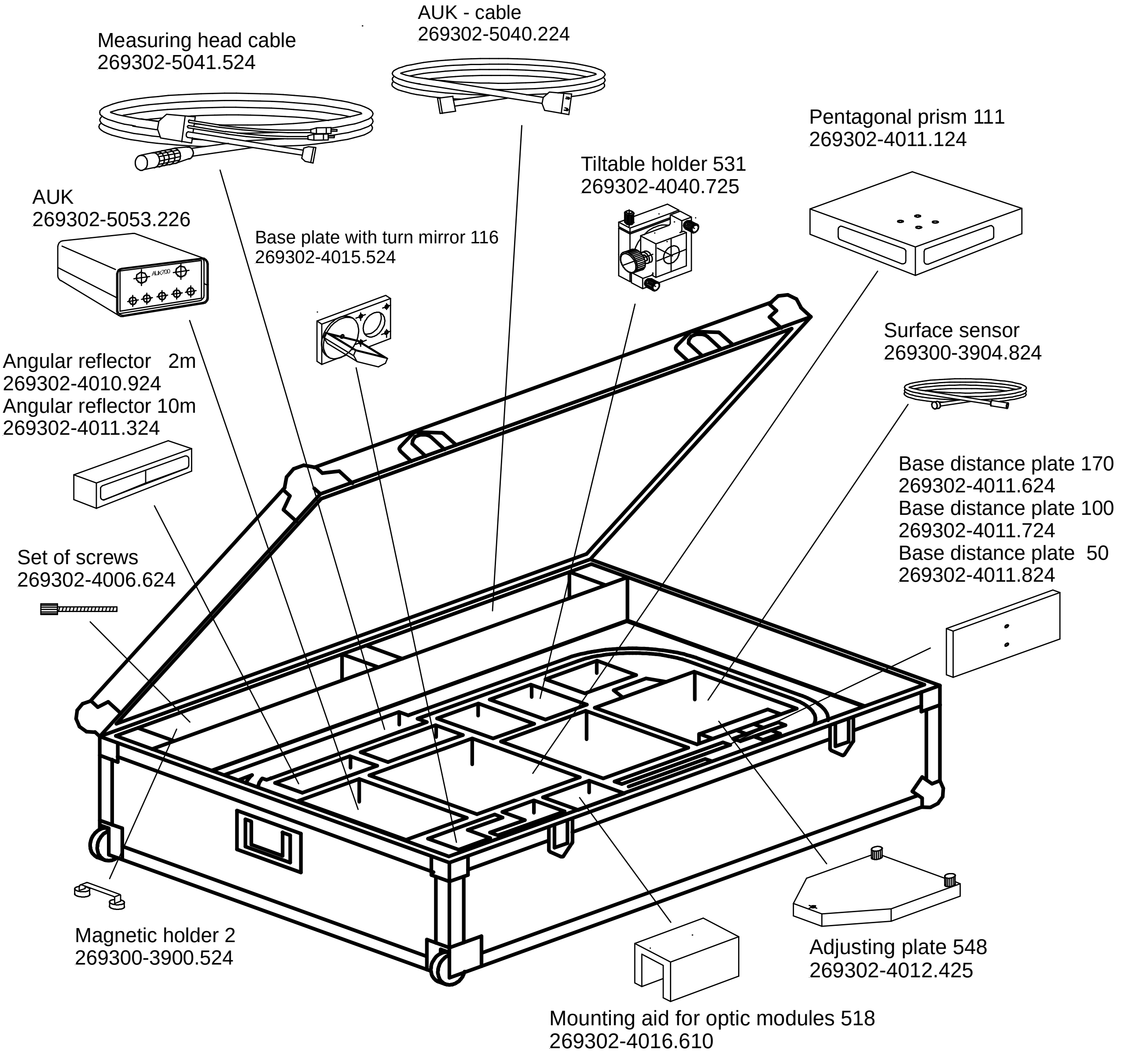
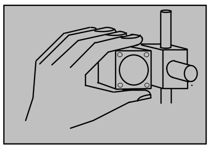


Fig. 7c: Roll case for taking in system ZLM 700 ***269302-4003.524***



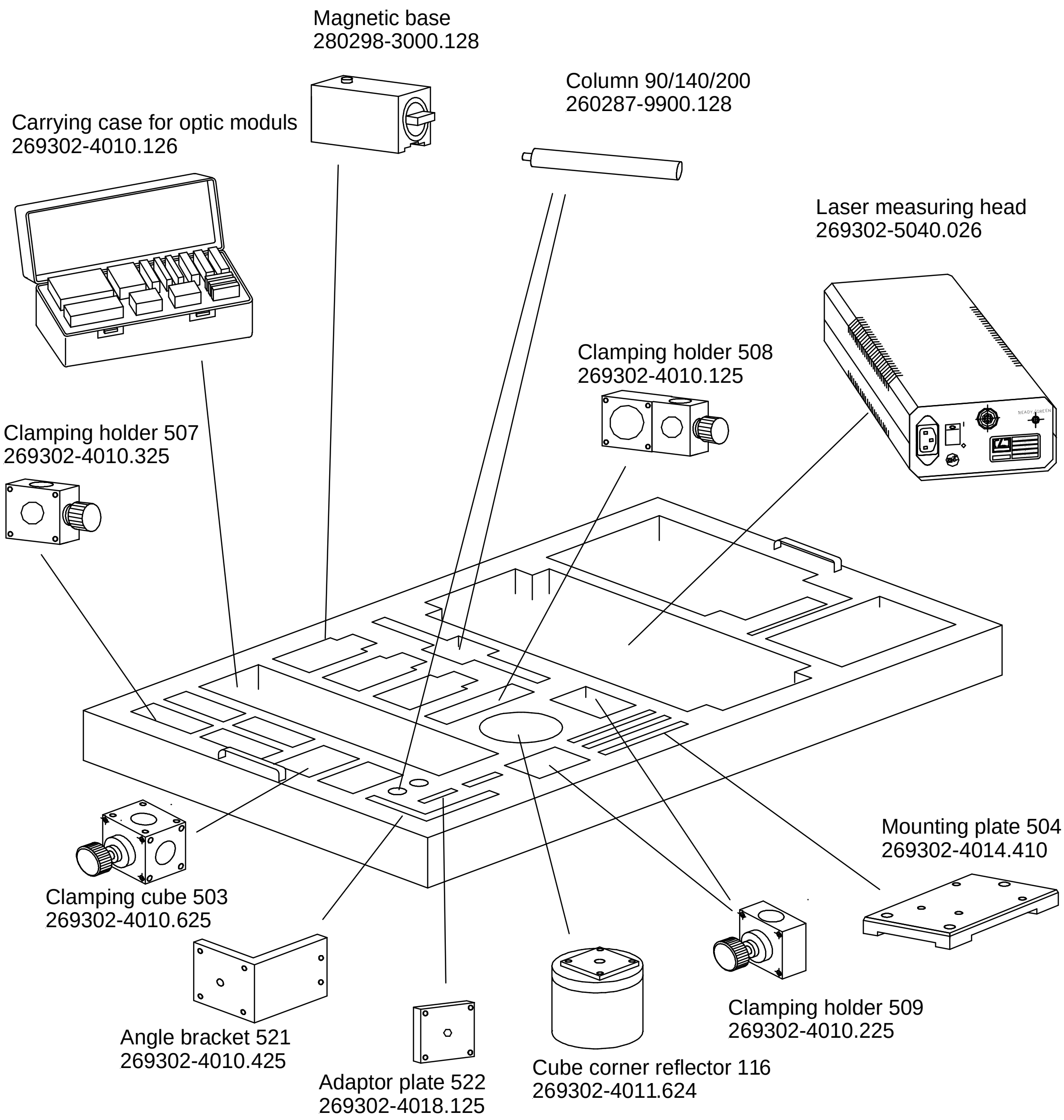
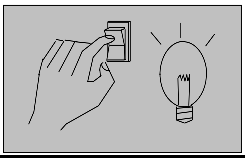


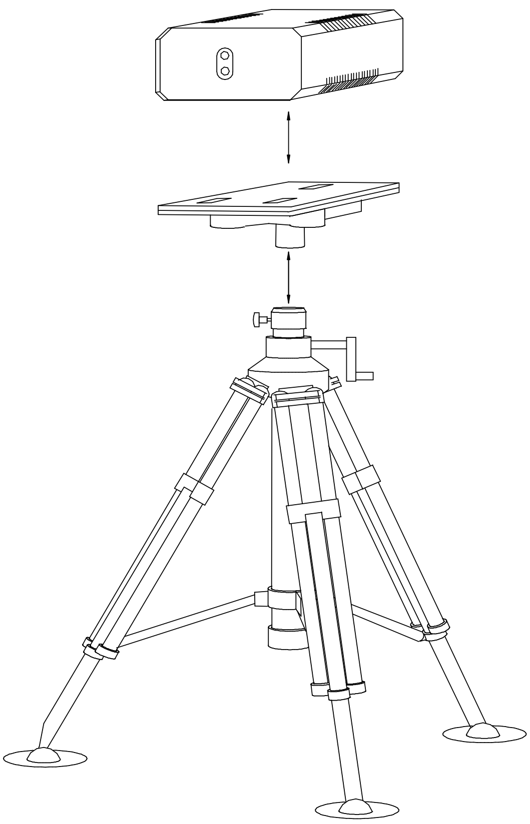
Fig. 7d: Insert for carrying case (roll case) for taking in system ZLM 700 ***269302-4003.524***



4. Overall System Startup

4.1. Assembling the Modules

All modules and components of the ZLM 700 Dual-Frequency Laser Interferometer come in sturdy shipment cases (Fig. 7a...d).Take laser head, adjusting table and tripod from the respective cases. Before putting them to use, allow them to adopt the ambient temperature.
Assemble the modules in the succession **Tripod - Adjusting table - Laser head.**



First spread the tripod legs to provide a stable position. Then remove the table fixing screw from the adjustable column. Slide the adapter bore of the adjusting table over the tripod column and fix the table to the column with the fixing screw (tighten well). Place the laser head on the adjusting table, first sinking its two conical feet into the corresponding seats of the table. Pull the arresting lever out of the table's third seat, press the laser head's third foot into the seat and let the arresting lever click back into position. The laser head is now positively connected with the table.

Connect the laser head to a power outlet via the mains cord. Now you can turn the laser on by actuating the power on/off switch at the rear end of the laser unit and start beam alignment. First effect coarse alignment between laser and the measuring object (optical components) by adjusting the tripod feet and displacing the tripod laterally.

Fig. 8 : Assembly of laser head, adjusting table and tripod.

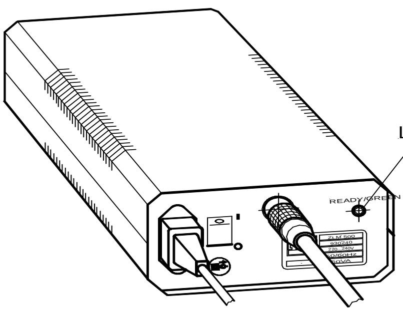


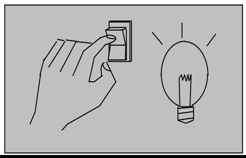
Fig. 9:
A LED at the rear end of the laser indicates wavelength stability.

RED:	The laser jumps between the modes.	⇨ Laser is **unstable**
GREEN:	The laser operates in the correct wavelength range	⇨ Laser is **stable**

As a rule, it takes the laser between 12 minutes to get stabilized.

IMPORTANT

If the temperatures of the laser and its environment differ greatly, it may take longer before stable operation is obtained.



After assembly and checking of the laser measuring head the overall system can be started up, which consists of:

Laser head, adjusting table, tripod,
Electronic evaluation unit AE 700 N or AE 700 PCI or AE 700cPCI PXI
PC
Optical modules
Automatic Environmental Sensor AUK.

ATTENTION!

Because of the EMC - compatibility and function the IBM-compatible PC ´s, Laptops and Dockingstations must be in receipt of CE-Certificate. Before PC ´s buying you should confer with JMT.

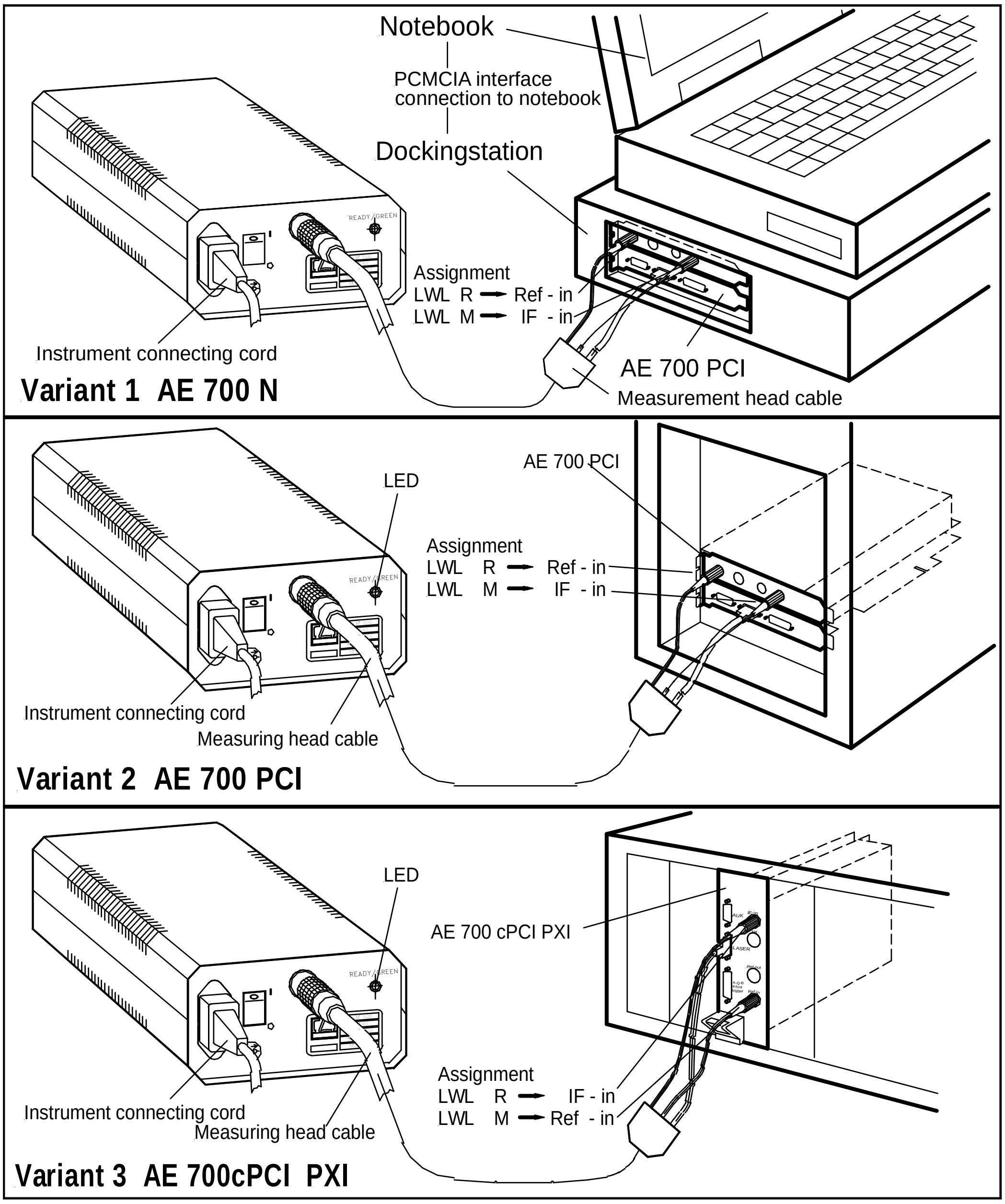
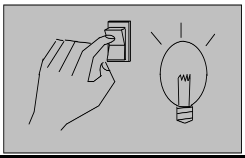


Fig. 10: Connections between laser head and electronic evaluation unit



ATTENTION!

Do not touch optical surfaces with fingers, and take care not to cause mechanical damage to these surfaces.
Please follow the warning labels on the laser head.

From laser measuring head connected electrical and optical transference conductions about the measuring head cable with one commom connector. Then the connection to evaluation unit is realized with separate connectors. The connections evaluation unit modules with PC's, laptops, notebooks and docking stations shows Fig.10.

ATTENTION!

Because of the Electromagnetic interferences EMI-compatibleness and functionality the IBM-compatible PC´s, laptops, notebooks and docking-stations must be certified at least CE.
It is advantageous, before purchase PC, to take consultation with JMT.

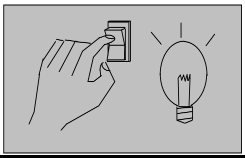
Connection AUK - evaluation unit is realized with AUK cable (no 269302-4040.224) The 15-point male connector of the cable is connected with the 15-pole female connector the evaluation unit and the 25-point male connector with the AUK.

Now all functions are ready for operation and can be made visible on the PC via the ZLM software (see the Software Manual).

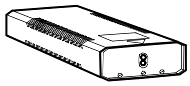
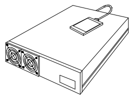
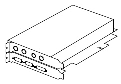
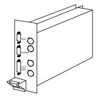
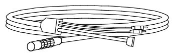
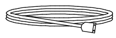
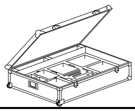
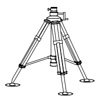
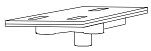
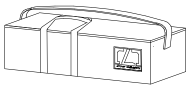
CAUTION

AE 700 – Moduls are not able „Hot-Plug"!

All connections must be ready before switching the net on!
Before connections will be interrupted the net must be switched off!



Basis equipment

Laser measuring head 269302-4040.026		Quantity:1
Evaluation units AE 700: **AE 700 N** 269302-5070.026 or **AE 700 PCI** 269302-5071.026 or **AE 700cPCI PXI** 269302-5072.026	  	Quantity:1
Measuring head cable *(2 fibre optic cables are integrated)* 269302-4010.325		Quantity: 1
Power cord 146.250		Quantity:1
Carrying case 269302-4003.526		Quantity:1
Tripod 4000.025		Quantity:1
Adjustable table 269302-4040.125		Quantity: 1
Carrying bag for tripod and adjustable table 4000.018		Quantity: 1

A Cube corner reflector Interferometer Configurations

Corner reflector interferometers are the most simple interferometer configurations. Those used for distance, speed and acceleration measurement consist of the following optical components (Fig. 1):

1 Polarizing beam splitter 101	*269302-4010.124*
1 Corner reflector 102 (reference)	*269302-4010.224*
1 Corner reflector 102 (measurement)	*269302-4010.224*

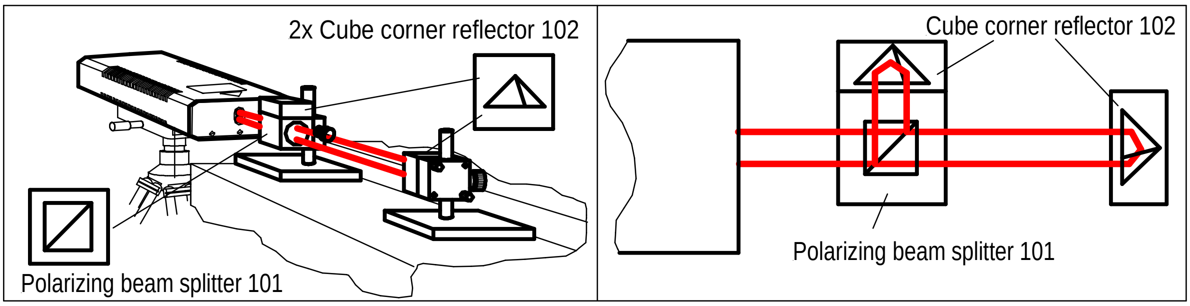


Fig. 1: Corner Reflector Interferometer (optical arrangement)

Functional description

The light emerging from the laser head serves as the measurement beam, which passes an interferometer arrangement followed by a measuring and a reference reflector, and strikes a detector E1. Because of a polarizing beam splitter in the interferometer, the measuring reflector only receives light of frequency f1, while the reference reflector only receives light of frequency f2. With the measuring reflector at rest, E1 detects the laser's differential frequency (f1 - f2 = 640 MHz), which is equal to the electronic reference signal (E2) detected in the laser head. As the measuring reflector is displaced, the beam portion of frequency f1, reflected by this reflector, is Doppler-shifted by ±df1. Accordingly, detector E1 registers a measuring frequency of Δf + df1 or Δf - df1, depending on which way the measuring reflector is moved. 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 (Fig. 2).

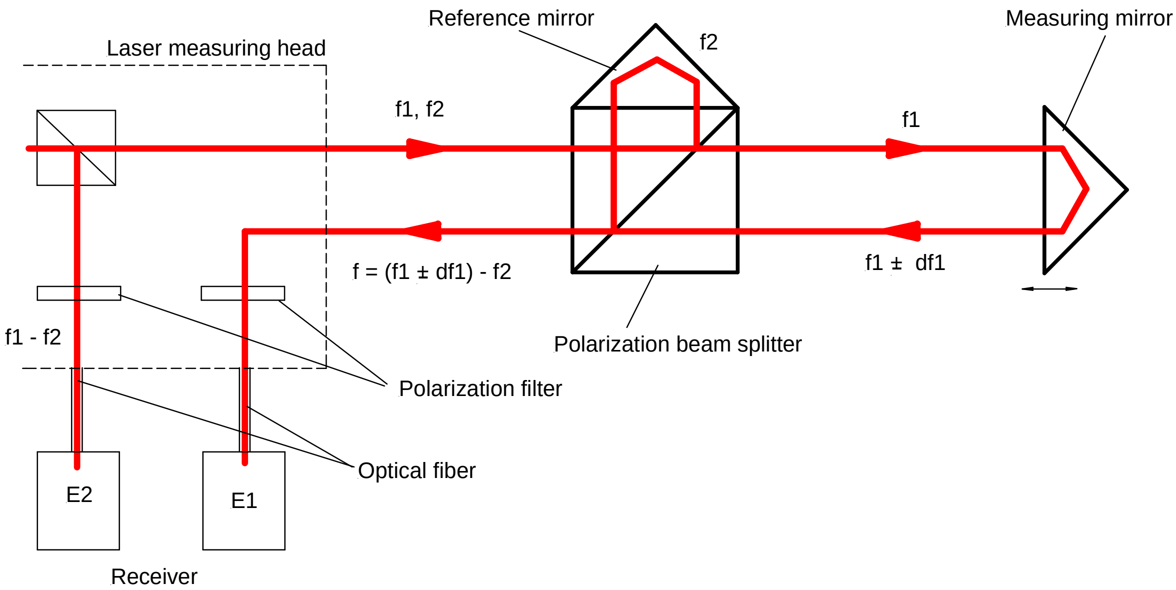


Fig. 2: Cube corner reflector interferometer (operating principle)

Assembly

Fig. 3 shows the optical and mechanical modules and components that make up a 2.5nm-resolution corner reflector interferometer. Fig. 1 presents the overall configuration of the functional system (the tripod and the adjustable table are not shown). Fig. 4 depicts the assembly of the modules and components, and Fig. 5 illustrates a practical application at a machine tool. Thanks to the system's modular design, other setups are also possible. For the contents of the carrying cases and the placement of the components therein, see Fig. 7 in section " Assembly of Modules and Components ".

Cube corner reflector interferometer
(distance measurement, 2.5 nm resolution)

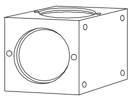
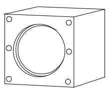
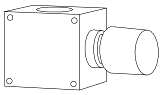
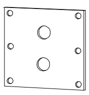
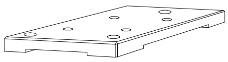
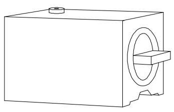
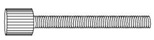
Polarizing beam splitter 101 269302-4010.124		Quantity: 1
Corner reflector 102 269302-4010.224		Quantity: 2
Clamping fixture 507 269302-4010.325		Quantity: 2
Beam stop plate 516 269302-4014.210		Quantity: 2
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic base 506 260298-3000.128		Quantity: 2
Column pin 140 260297-9900.128		Quantity: 2
Set of screws 269302-4005.624		Quantity: 1

Fig. 3: Optical and mechanical components of the Corner Reflector Interferometer

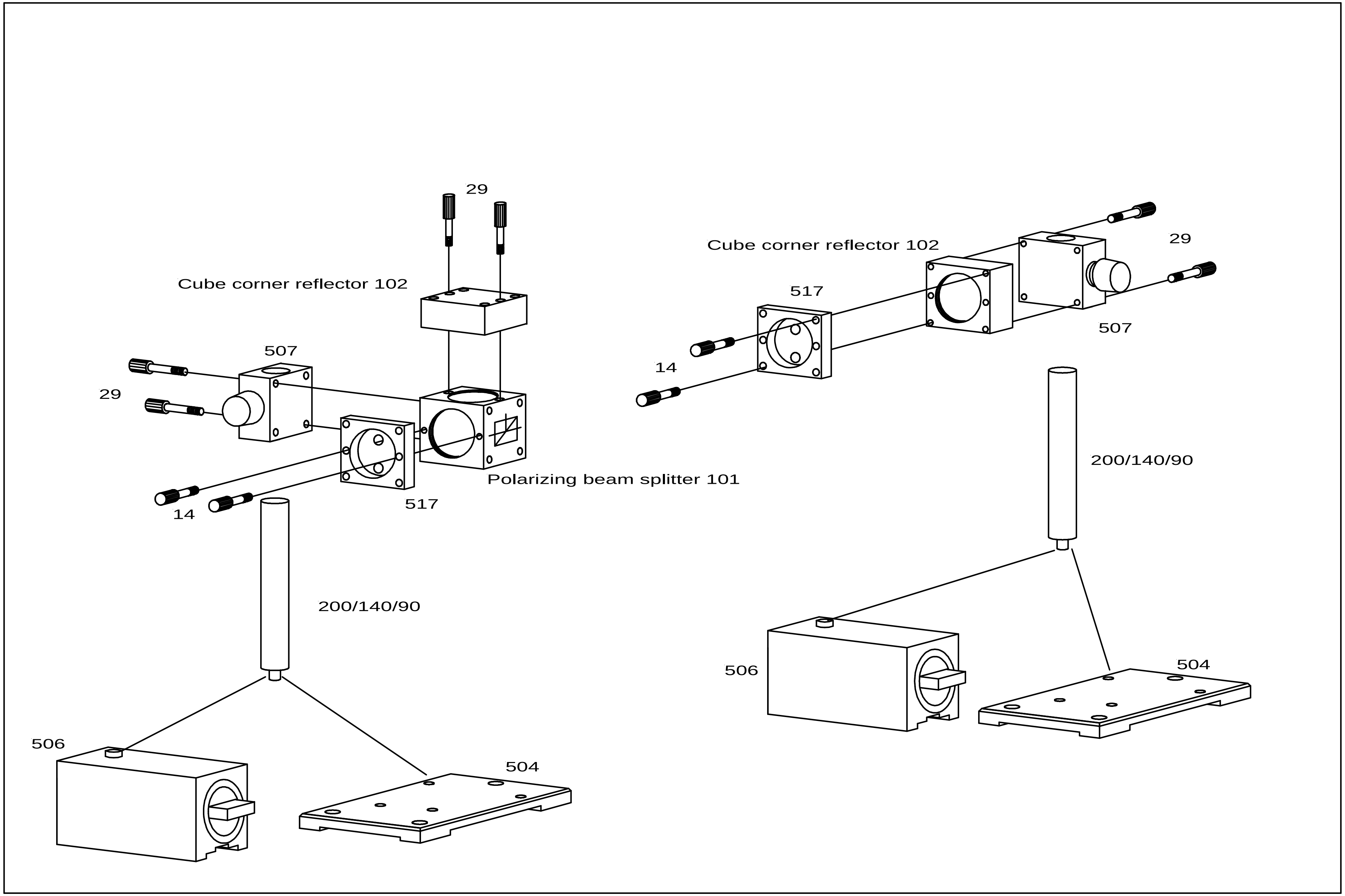


Fig. 4: Assembly of the modules and components

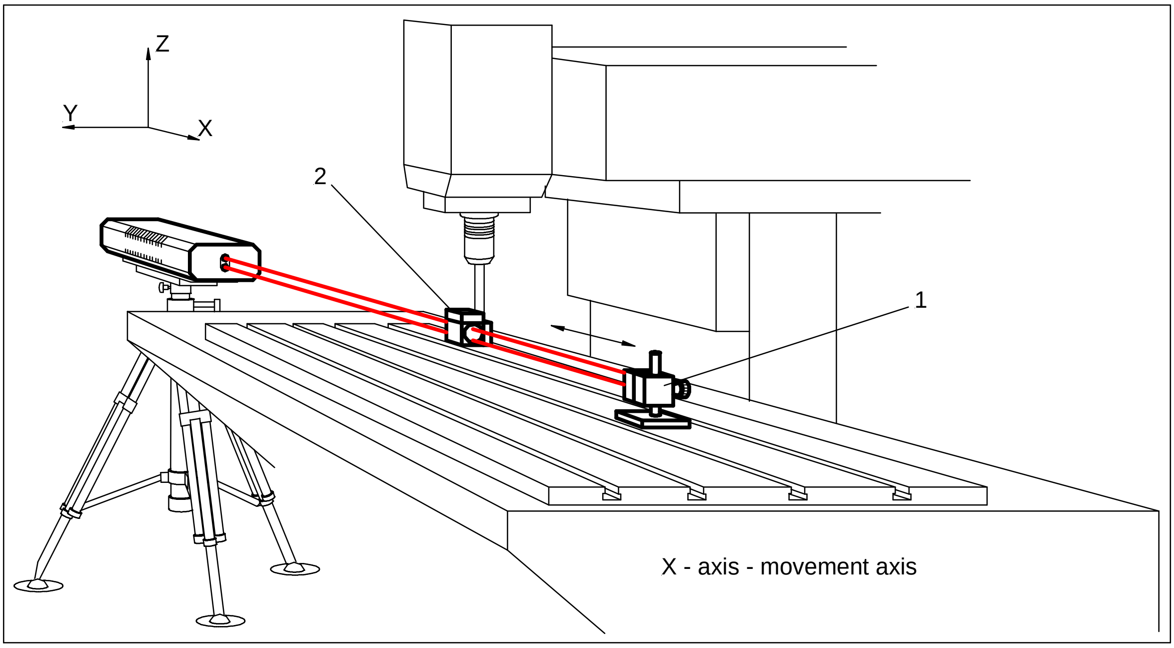


Fig. 5: Measurement setup at a machine tool

Measurement assembly

With all modules and components assembled, the configuration consisting of **laser head, interferometer and cube corner reflector** can be set up on the object to be measured. The setting-up procedure should follow the sequence of steps described below:

1. Identify the axis of motion to be measured and find a location on the moving part of the object where the optical system can be fixed (1).
2. Find a stationary reference point in line with the axis of movement (2).

> **IMPORTANT:**
> The optical modules must be so located that the point of location on the motion axis, the stationary reference point of fixing the interferometer and the beam exit port of the laser head can be aligned on a line in parallel with the motion axis (Fig. 6).

3. Fix the optical modules at the locating points found, wherever possible, in order to reduce measurement errors:

Interferometer	stationary reference point (2)
Cube corner (measuring) reflector	movable reference point (1)

> **IMPORTANT:**
> Interferometer and corner reflector must have equal distances to the measuring line (h1 = h2 in Fig. 6) in order to avoid angular errors.

4. Roughly align the laser beam with the optical axis of the installed optical modules.

Tips:

(1) Position the laser head as closely as possible to the interferometer.
(2) Position the corner reflector at the most distant point possible from the interferometer.
(3) Check whether the adjustable table is at the centre of its parallel displacement and tilting ranges. ⇨ This is important to ensure sufficient freedom of adjustment both ways during fine alignment of the beam path.

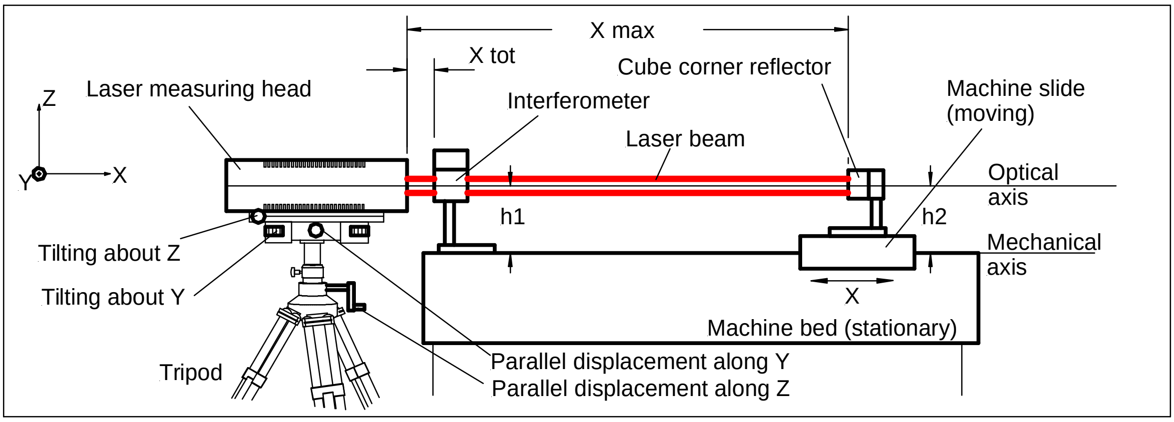


Fig. 6: Measuring setup, optical path

5. Fine alignment of the beam path

Tip:

To facilitate the alignment of the optical path in parallel with the measuring axis, remove the interferometer from the beam path, leaving only the corner reflector. ⇨ That way, only one beam returns to the laser head, which makes it easier to assess the state of alignment.

A fundamental distinction is made (Fig. 7) between

- positional alignment (Δy, Δz) (parallel displacement along y and z)
- directional alignment (Δϕy, Δϕz) (tilting about y and z)

The ZLM 700 is designed so that both adjustment facilities are provided on the adjustable table / tripod assembly. The merit of this arrangement is that you do not have to constantly alternate between two adjusting locations (laser head - measuring reflector).

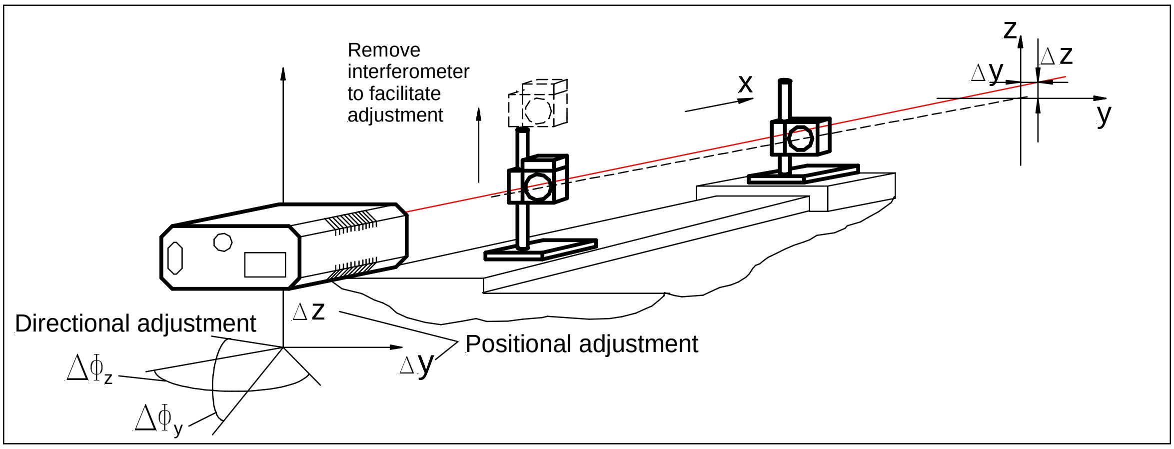


Fig. 7: Alignment of the beam path

The location of the cube corner reflector relative to the interferometer is important for both positional and directional alignment (Fig. 8):

Positional alignment, Parallel displacement ⇨ at the cube corner reflector position nearest to the laser

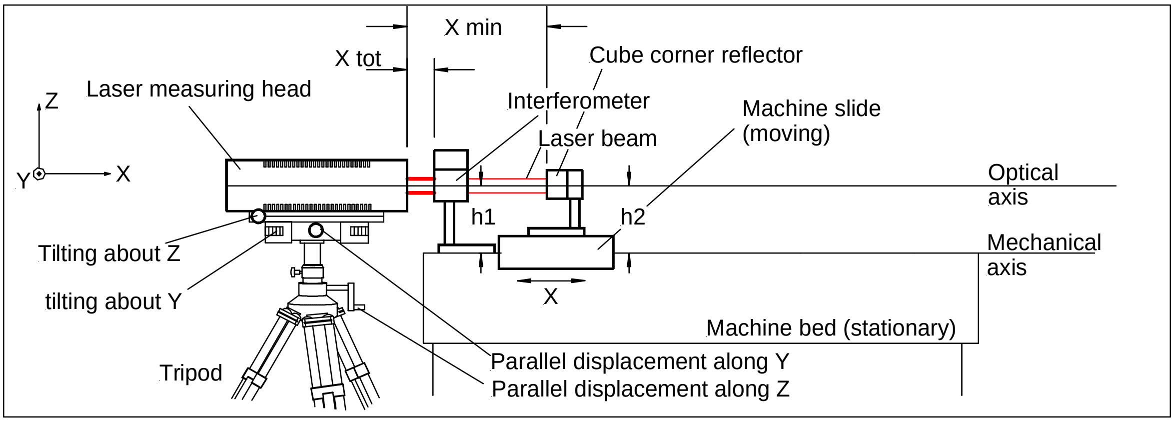


Fig. 8: Positional alignment of the beam path

Directional alignment, tilting ⇨ at the corner reflector position most distant from the laser head

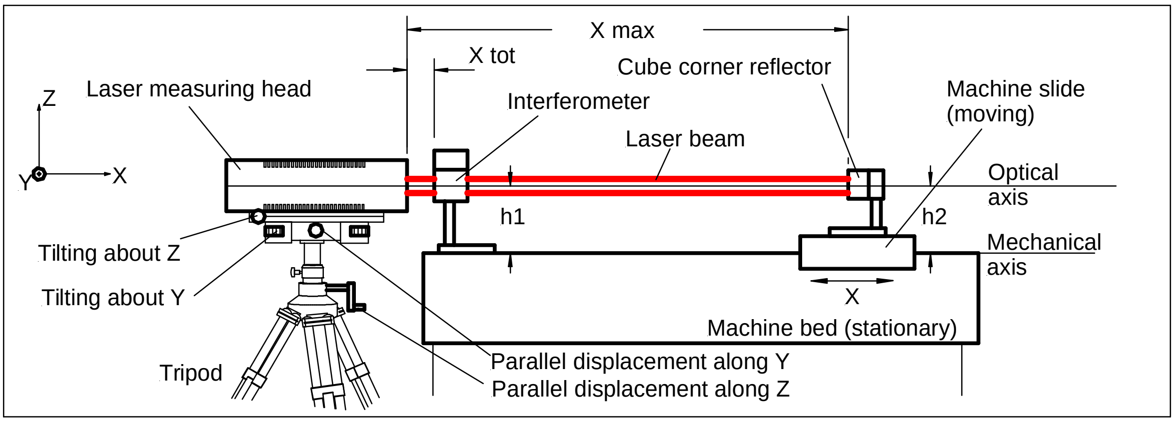
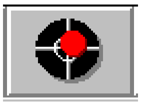


Fig. 9: Directional alignment of the beam path

Adjustment

From these basic principles, the following procedure of aligning the beam path results:

1) Select menu item  in the "Measurement" program routine.
   In this menu item, the powers of the two beams reflected back into the laser head (reference and measuring beams) are represented by two spots on the monitor screen. The screen graph immediately shows the effect of alignment manipulations and thus allows the quality of alignment of the two beams to be checked and optimized.

2) Move cube corner reflector to the point most distant from the laser head and fix it there (Fig. 9).
   Adjust the laser beam direction in y and z:

   $\Delta\Phi y$ - Turn the two lateral knurled screws of the adjustable table;
   $\Delta\Phi z$ - Turn the two knurled height adjustment screws of the adjustable table.

   Align until the reflected beam hits the beam entrance port of the laser head.
   For fine alignment, use the cross-lines shown on the screen.

3) Move cube corner reflector to the point closest to the laser and fix it there (Fig. 8).
   Adjust the laser position in y and z:

   Δy - Turn the micrometer screw of the adjustable table to displace the laser in parallel.
   Δz - Turn the height adjustment handwheel of the tripod.

   Align until the reflected beam hits the beam entrance port of the laser head.
   For fine alignment, use the cross-lines shown on the screen.

   Repeat steps 2 and 3 alternatingly until no significant change in beam position (relative to the screen cross-lines) can be noticed.
   The permanent angular error between the optical and mechanical axes can be seen as the blue moving bar below the cross-lines presentation.

IMPORTANT:

Pay attention to the same local situation of the points of measuring and reference beam in the cross-lines.
(importantly for perfect interferenc signal)

Aligning the interferometer completes the alignment of the setup, which is now ready for measurement (see the Software Manual).

Extension of the measuring construction for the diagonal measurements

The measuring construction described in the previous section is suitable for the orthogonal measurement of axes to machine tools, coordinate measuring machines, Industrial roboter and so on.
This means that the measurings of the coordinate axises (X -, Y - and Z - axis) are made separately and independently of each other.
For measuring diagonal movements (consists of simultaneous x-, y- and z-movings) the extension kit named **“Diagonal measurement”** is needed.

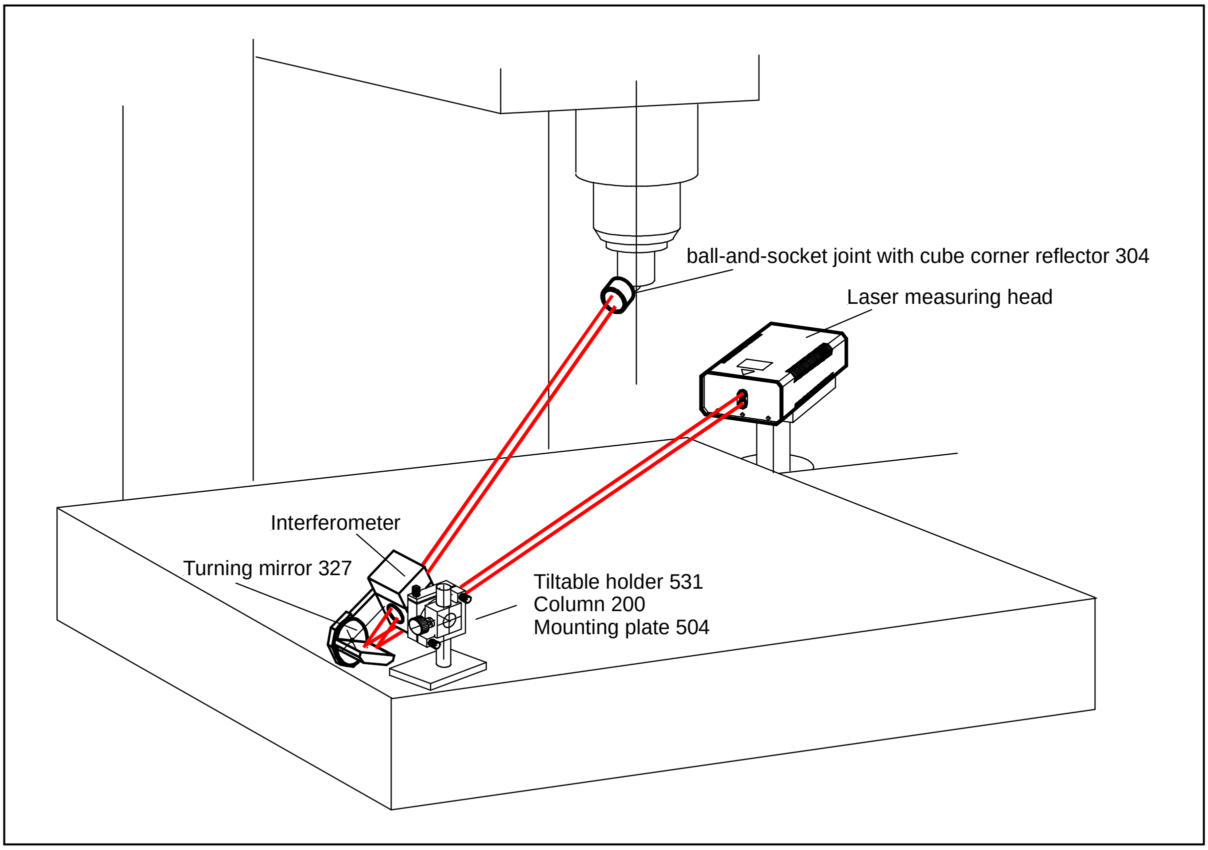


Fig. 10: Optical setup for diagonal measurement at a machine

By the tiltable holder 531 the interferometer can be taken to the diagonal direction of axis.
The cube corner reflector is swung in the direction by a ball-and-socket joint.
The cone (dmr 15) of the ball-and-socket joint can be put in to the toolhead of the machine without problems.
The interferometer is completed with the tiltable mirror 327. Thereby the laser measuring head can keep its horizontal position during the diagonal measurements.

Fig. 11 shows the optical and mechanical modules and components of the extension kit for diagonal measurement

Extension kit for diagonal measurement

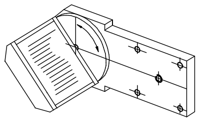
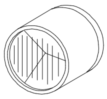
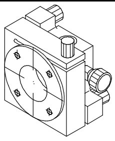
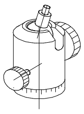
Turning mirror 327 269302-4013.724		Quantity: 1
Cube corner reflector 304 269302-4059.124		Quantity: 1
Tiltable holder 531 269302-40.725		Quantity: 1
Ball-and-socket joint 260297-9900.628		Quantity: 1

Fig. 11: Optical and mechanical modules and components

The assembly of the optical components, the mechanical mounting and adjusting elements is illustrated into Fig. 12.

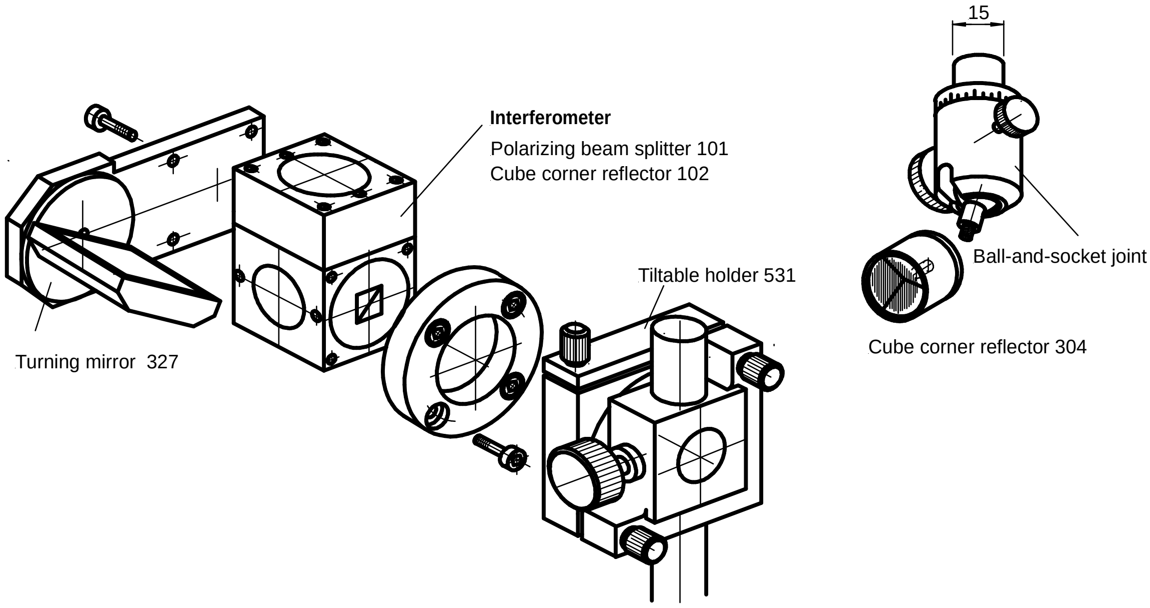


Fig. 12: Setup of the optics for the diagonal measurement

Adjustment

The justification of the Michelson interferometer was already described in detail in the previous chapter. At the diagonal measuring is in addition between interferometer and laser measuring head a turning mirror.
The right adjustment of the turning mirror 327 is shown in the Fig. 13.
The turning mirror 327 is always adjust around half the amount of the angle between the horizontal beam direction (of the laser measuring head) to the diagonal measuring direction

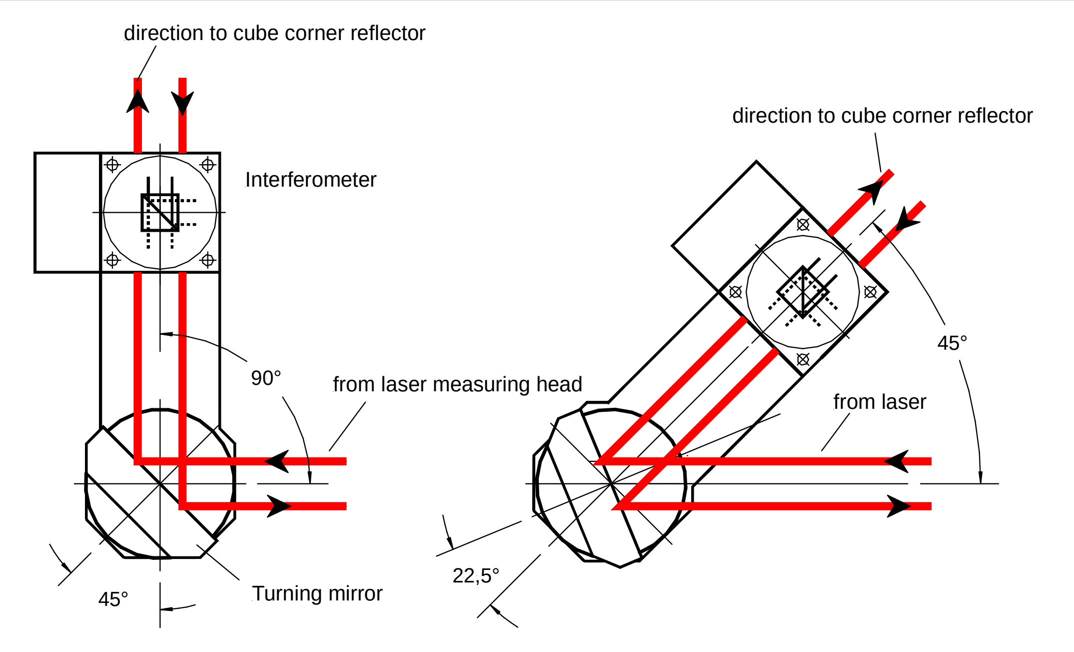


Fig. 13: Adjustment of the turning mirror 327
(example 1: 90° angle between measuring direction and incident laser beam
example 2: 45° angle between measuring direction and incident laser beam)

Diagonal measurements in an angular range between 22,5° and 135° can be realized by the extension kit “Diagonal measurement” (Fig. 14)

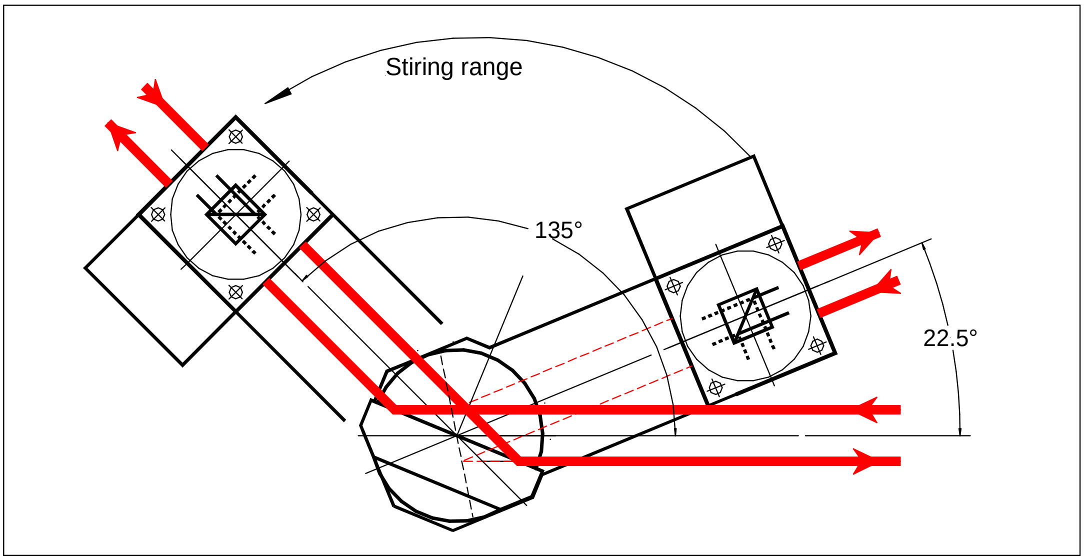


Fig. 14: Tilting range of the turning mirror for the diagonal measurements

B Plane Mirror Interferometer Configurations

Plane mirror interferometers are the ideal solution for special duty with a resolution of 1.25nm. Those used for distance, speed and acceleration measurement consist of the following optical components (Fig. 1):

1	**Polarizing beam splitter 101**	*269302-4010.124*
1	**Corner reflector 102**	*269302-4010.224*
1	**Plane mirror 103 (reference)**	*269302-4010.324*
1	**Plane mirror 103 (measurement)**	*269302-4010.324*
2	**λ/4-Plate 104**	*269302-4010.424*

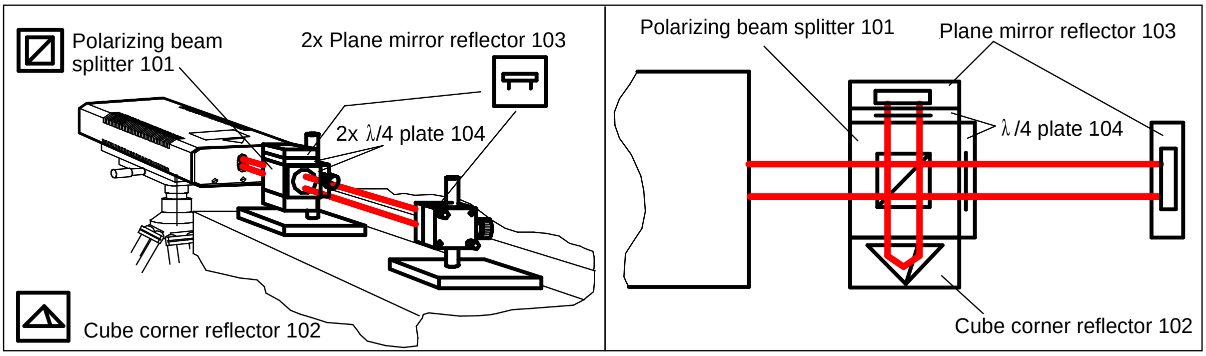


Fig. 1: Plane Mirror Interferometer (optical arrangement)

Functional description

The light emerging from the laser head serves as the measurement beam, which passes an interferometer arrangement followed by a measuring and a reference reflector, and strikes a detector E1. Because of a polarizing beam splitter in the interferometer, the measuring reflector only receives light of frequency f1, while the reference reflector only receives light of frequency f2.

Passing the retardation plates (λ/4 - plates) the both frequencies are circularly polarized. On return back the measurement beam (reflected by the plane mirror) is reflected by the polarizing beam splitter coating. The reference beam is not reflected by the polarizing beam splitter coating.
The two beams are reflected by the corner reflector and then they travel to their respective plane mirror again. When they pass the retardation plates last time, the both frequencies are linearly polarized. The total of turns of polarization direction is an angle of 180° (same at to begin). The reference beam is reflected back into the laser head by the polarizing beam splitter coating. The measurement beam passes the coating and enters the laser head.

With the measuring reflector at rest, E1 detects the laser's differential frequency (f1 - f2 = 640 MHz), which is equal to the electronic reference signal (E2) detected in the laser head. As the measuring reflector is displaced, the beam portion of frequency f1, reflected by this reflector, is Doppler-shifted by ± 2df1. Accordingly, detector E1 registers a measuring frequency of Δf + 2df1 or Δf - 2df1, depending on which way the measuring reflector is moved. 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 ±2df1 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 (Fig. 2).

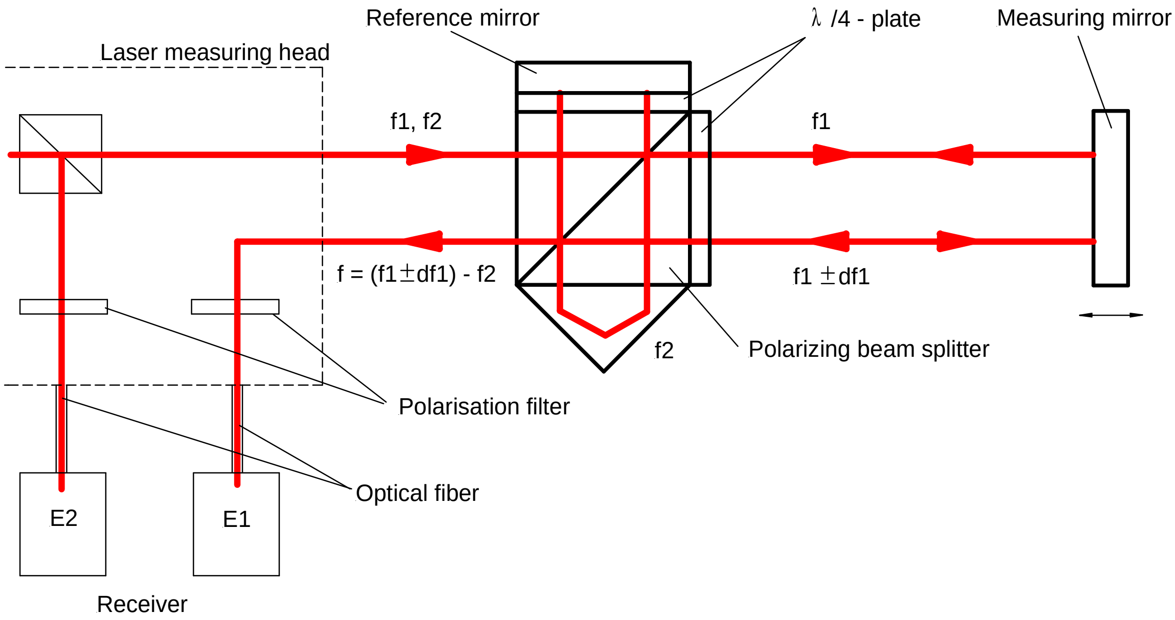


Fig. 2: Plane mirror interferometer (operating principle)

Assembly

Fig. 3 shows the optical and mechanical modules and components that make up a 1.25nm-resolution plane mirror interferometer. Fig. 1 presents the overall configuration of the functional system (the tripod and the adjustable table are not shown). Fig. 4 depicts the assembly of the modules and components, and Fig. 5 illustrates a practical application at a machine tool. Thanks to the system's modular design, other setups are also possible. For the contents of the carrying cases and the placement of the components therein, see Fig. 7 in section "Assembly of Modules and Components".

Plane Mirror Interferometer
(distance measurement, 1.25nm resolution)

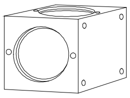
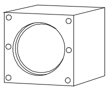
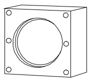
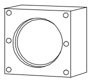
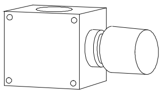
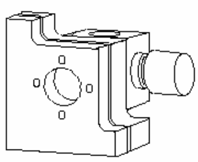
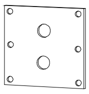
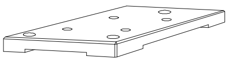
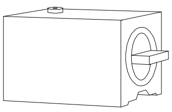
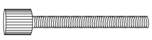
Polarizing beam splitter 101 269302-4010.124		Quantity: 1
Corner reflector 102 269302-4010.224		Quantity: 1
Plane mirror 103 269302-4010.324		Quantity: 2
λ/4-Plate 104 269302-4010.424		Quantity: 2
Clamping fixture 507 269302-4010.325		Quantity: 1
Clamping fixture 532 269302-4040.625		Quantity: 1
Beam stop plate 516 269302-4014.210		Quantity: 2
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic chuck 506 260298-3000.128		Quantity: 2
Column pin 140 260297-9900.128		Quantity: 2
Set of screws 269302-4005.624		Quantity: 1

Fig. 3: Optical and mechanical components of the Plane Mirror Interferometer

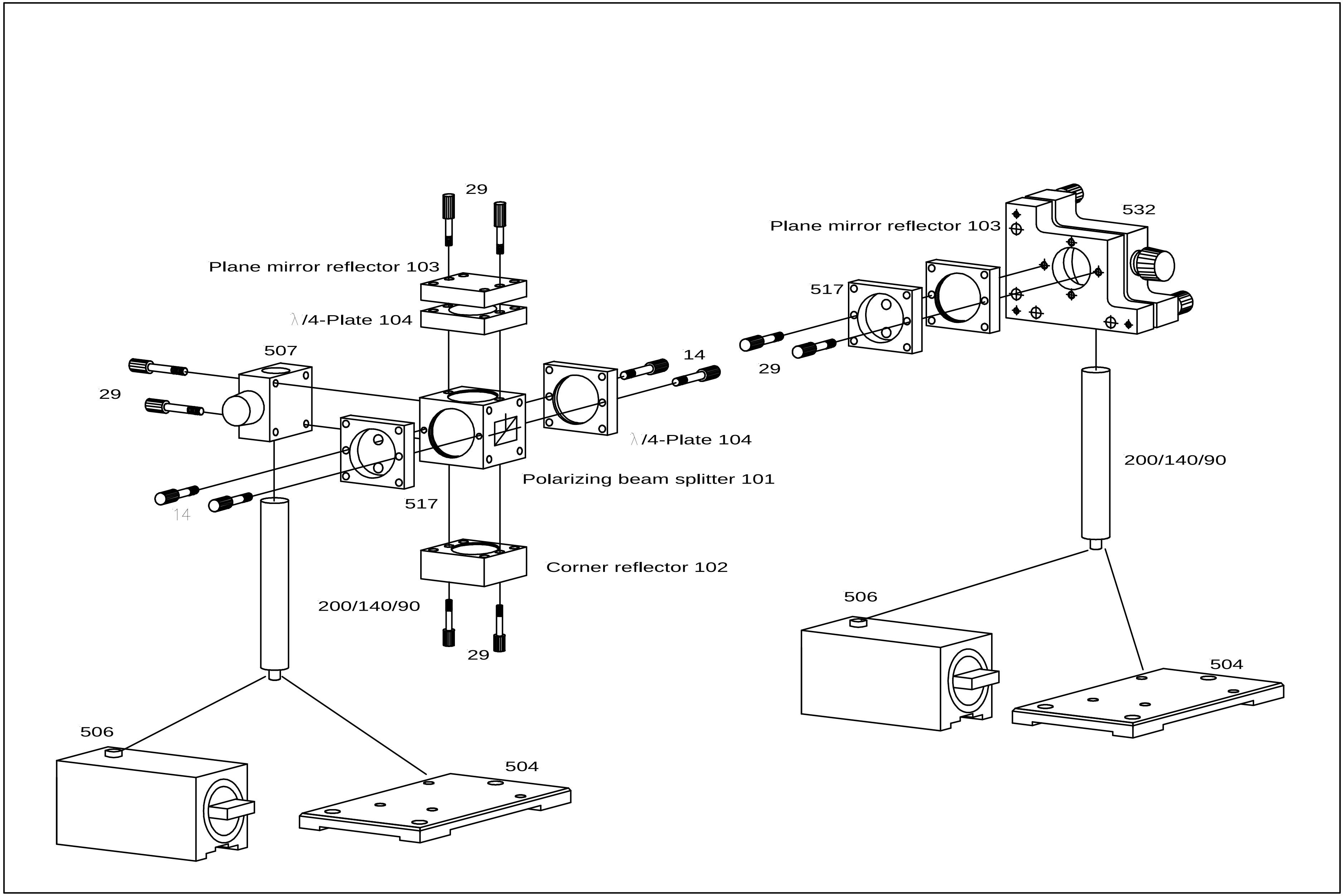


Fig. 4: Optical assembly

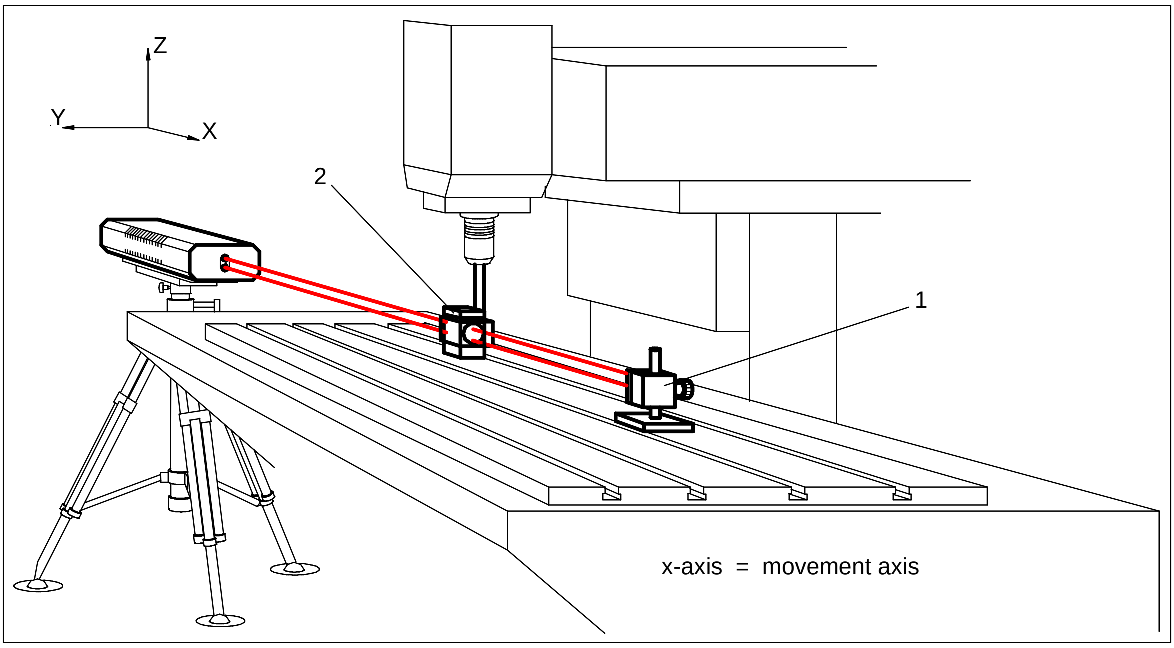


Fig. 5: Measurement setup at a machine tool

Measurement assembly

With all modules and components assembled, the configuration consisting of **laser head, interferometer and plane mirror** can be set up on the object to be measured. The setting-up procedure should follow the sequence of steps described below:

1. Identify the axis of motion to be measured and find a location on the moving part of the object where the optical system can be fixed (1).

2. Find a stationary datum point in line with the axis of movement (2).

> **IMPORTANT:**
> The optical modules must be so located that the point of location on the motion axis, the stationary datum point of fixing the interferometer and the beam exit port of the laser head can be aligned on a line in parallel with the motion axis (Fig. 6).

3. Fix the optical modules at the locating points found, wherever possible, in order to reduce measurement errors:

Interferometer	stationary reference point (2)
Plane (measuring) reflector	movable reference point (1)

> **IMPORTANT:**
> Interferometer and plane mirror must have equal distances to the measuring line (h1 = h2 , Fig. 6) in order to avoid angular errors.

4. Roughly align the laser beam with the optical axis of the installed optical modules.

Tips:

(1) Position the laser head as closely as possible to the interferometer.
(2) Position the plane mirror at the most distant point possible from the interferometer.
(3) Check whether the adjustable table is at the centre of its parallel displacement and tilting ranges. This is important to ensure sufficient freedom of adjustment both ways during fine alignment of the beam path.

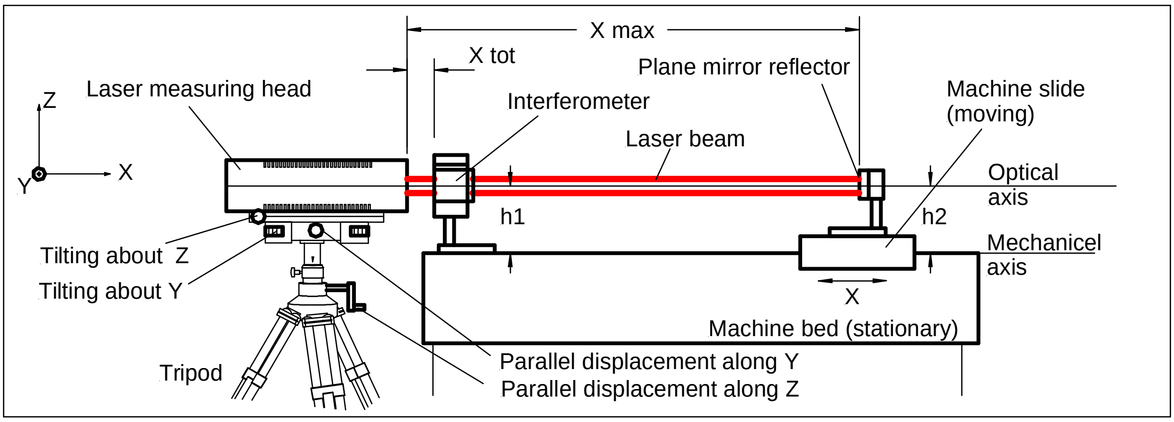


Fig. 6: Measuring setup, optical path

5. Fine alignment of the beam path

Tip:

To facilitate the alignment of the optical path in parallel with the measuring axis, remove the interferometer from the beam path, leaving only the plane mirror. That way, only one beam returns to the laser head, which makes it easier to assess the state of alignment.

A fundamental distinction is made (Fig. 7) between

positional alignment	(parallel displacement along x and y) (δx, δy)
and	
directional alignment	(tilting about x and y) (δϕx, δϕy)

The ZLM 700 is designed so that both adjustment facilities are provided on the adjustable table / tripod assembly. The merit of this arrangement is that you do not have to constantly alternate between two adjusting locations (laser head - measuring reflector).

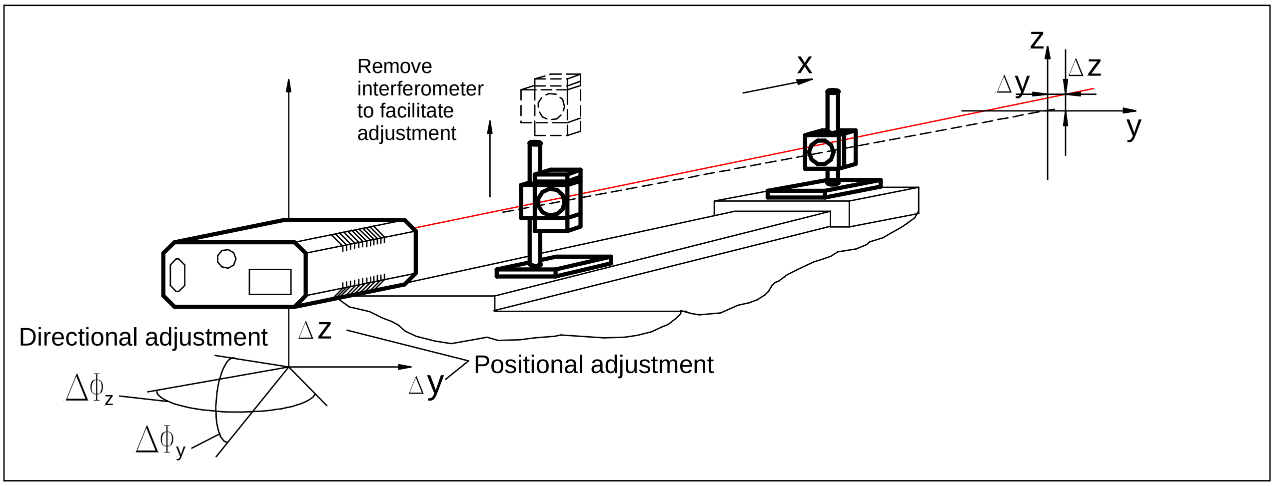


Fig. 7: Alignment of the beam path

The location of the plane mirror relative to the interferometer is important for both positional and directional alignment (Fig. 8):

Positional alignment,
parallel displacement ⇨ at the plane mirror position nearest to the laser

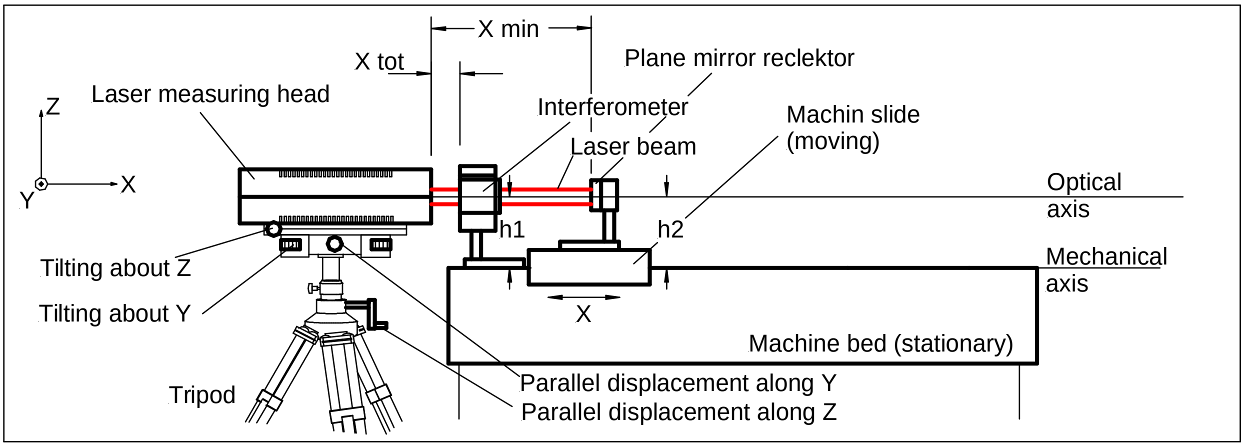


Fig. 8: Positional alignment of the beam path

Directional alignment, tilting	⇨	at the plane mirror position most distant from the laser head

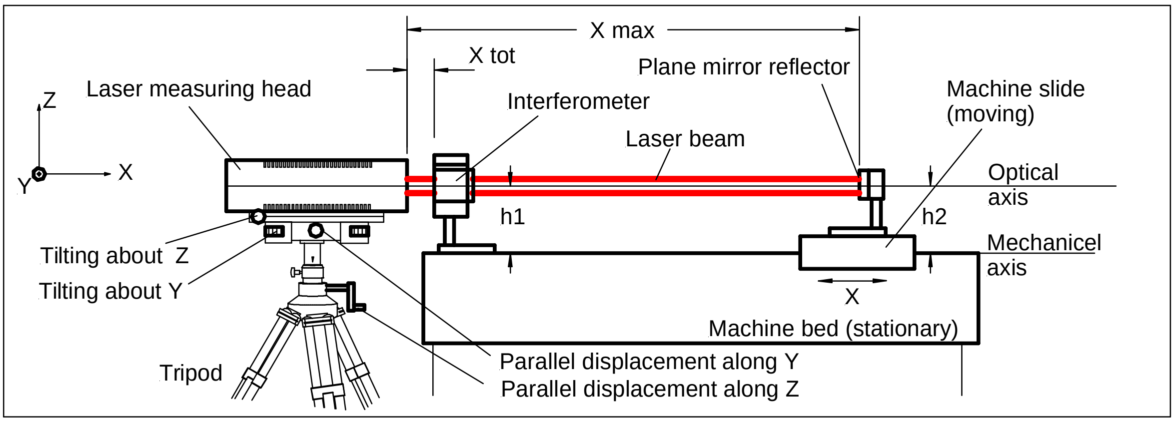
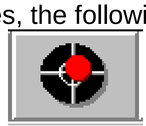


Fig. 9: Directional alignment of the beam path

Adjustment

From these basic principles, the following procedure of aligning the beam path results:

1. Select menu item  in the "Measurement" program routine.
   In this menu item, the powers of the two beams reflected back into the laser head (reference and measuring beams) are represented by two spots on the monitor screen. (prerequisite: alignment the interferometer in the beam path) The screen graph immediately shows the effect of alignment manipulations and thus allows the quality of alignment of the two beams to be checked and optimized.

2. Move plane mirror to the point most distant from the laser head and fix it there (Fig. 9).
   Adjust the laser beam direction in y and z:

   $\Delta\Phi y$ - Turn the two lateral knurled screws of the adjustable table,
   $\Delta\Phi z$ - Turn the two knurled height adjustment screws of the adjustable table.

   Align until the reflected beam hits the beam entrance port of the laser head.
   For fine alignment, use the cross-lines shown on the screen.

3. Move the plane mirror to the point closest to the laser and fix it there (Fig. 8). Adjust the laser position in y and z:

   Δy - Turn the micrometer screw of the adjustable table to displace the laser in parallel.
   Δz - Turn the height adjustment handwheel of the tripod.

   Align until the reflected beam hits the beam entrance port of the laser head.
   For fine alignment, use the cross-lines shown on the screen.

Repeat steps 2 and 3 alternatingly until no significant change in beam position (relative to the screen cross-lines) can be noticed.
The permanent angular error between the optical and mechanical axes can be seen as the blue moving bar below the cross-lines presentation.

IMPORTANT:

Pay attention to the same local situation of the points of measuring and reference beam in the cross-lines.
(importantly for perfect interferenc signal education)

Note:
The aligning of the interferometer doesn't influence the adjusted beam path of the plane mirror.

Aligning the interferometer completes the alignment of the setup, which is now ready for measurement (see the Software Manual).

C Interferometer with cube corner reflectors for the angle measuring

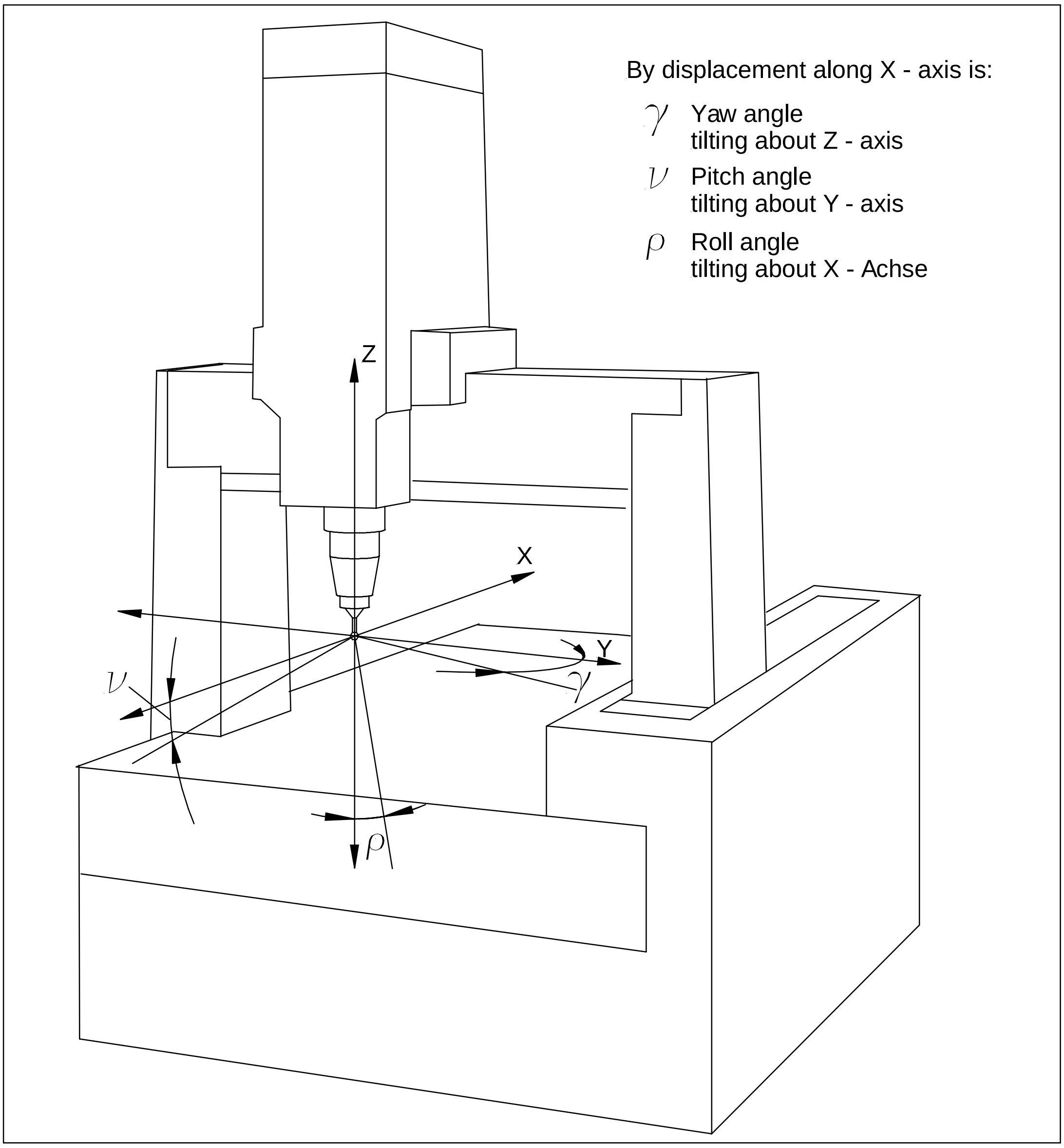


Fig. 1: Tilt angle at a coordinate measuring machine

To the detection of yaw and pitch angle errors of machine tools, coordinate measuring machines etc. as well as for the solution of other angle measurement problems special angle interferometers can be used. These consist of the optics modules:

1 Angle interferometer 114	***269302-4015.324***
1 Double corner reflector 115	***269302-4015.424***

If a position or distance measuring was already carried out, the construction can be converted by simple exchange of the optics modules without long adjustment of angle measurement. The parallelism of the angle interferometer makes it possible to measure angles on guide way lengths to 20 m.

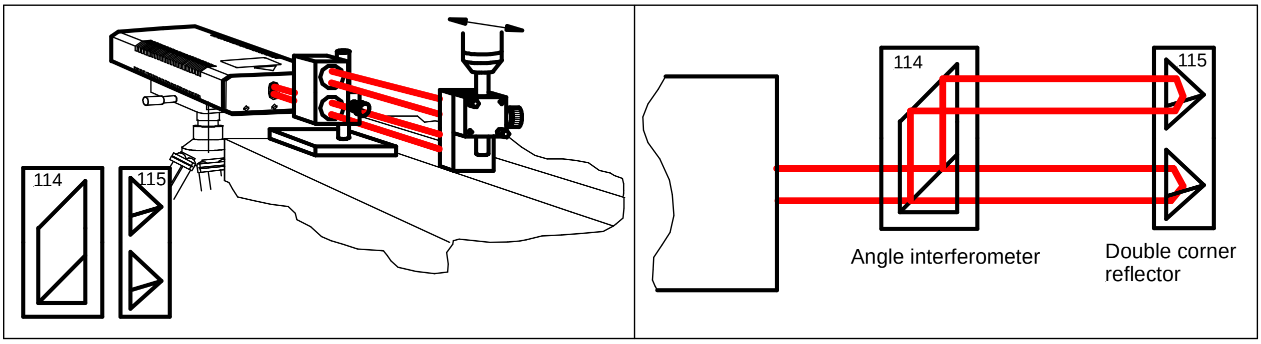


Fig. 2: Optical arrangement: angle interferometer for the pitch angle measuring
(for the yaw angle measuring: turn angle interferometer and double corner reflector by 90°)

For special measurement tasks there is the possibility to realize the construction of an angle interferometer with the standard optics modules (Fig. 3).

<u>Angle interferometer with standard optical modules:</u>

1 Polarizing beam splitter 101 269302-4010.124
1 90° Beam bender 110 269302-4011.024
2 Cube corner reflector 102 269302-4010.224

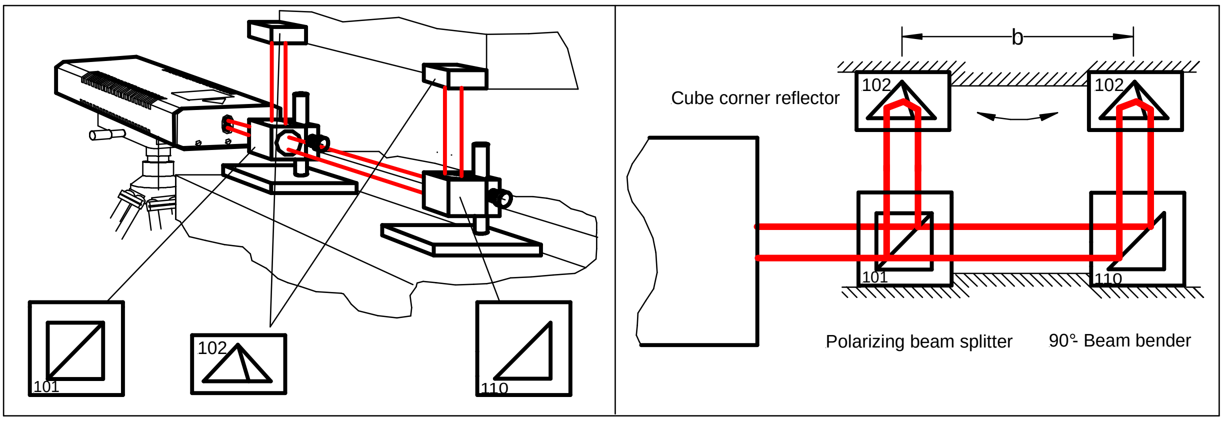


Fig. 3: Optical arrangement: angle interferometer with the standard optics modules

<u>Angle interferometer with straightness optical modules:</u>

1 Straightness interferometer 128 269302-4012.824
1 Double corner reflector 160 269302-4014.424
if necessary
1 Beam offset prism120 269302-4008.424

With Straightness interferometer 128 and Double corner reflector 160 is it possible to make angle measurements.

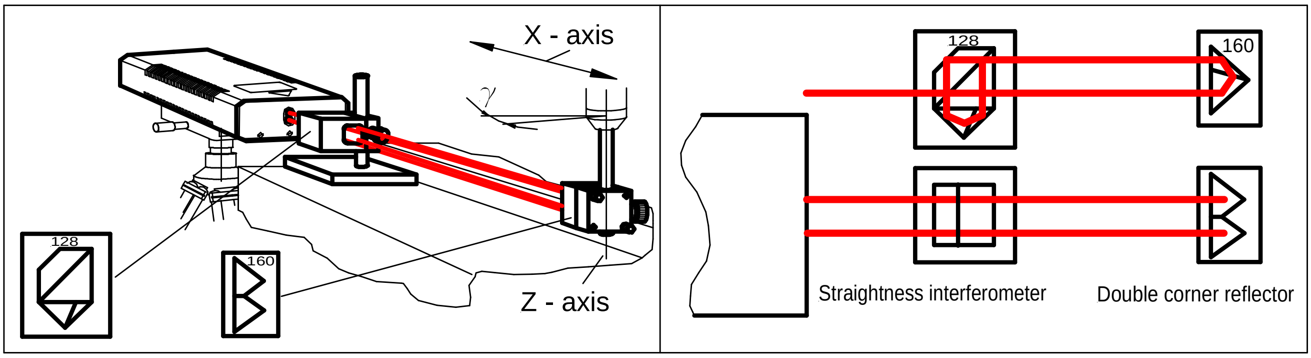


Fig. 4: Optical arrangement: angle interferometer (Straightness interferometer 128 with cube corner reflector 160) for the yaw angle measuring
(for the pitch angle measuring: turn angle interferometer and double corner reflector by 90°)

Fig. 4 shows the optical arrangement of yaw angle measurement with straightness interferometer 128 and double corner reflector 160. The measuring of the pitch angle is also possible with this interferometer variant. Straightness interferometer and Cube corner reflector must be turned by 90° for assembling.

The beam offset prism 120 is to install in addition, so that the beam coming back off the interferometer can enter the laser measuring head again.
In beam offset prism taking place a beam redirection about diagonal and in order that a shifting to 90° (Fig. 5).

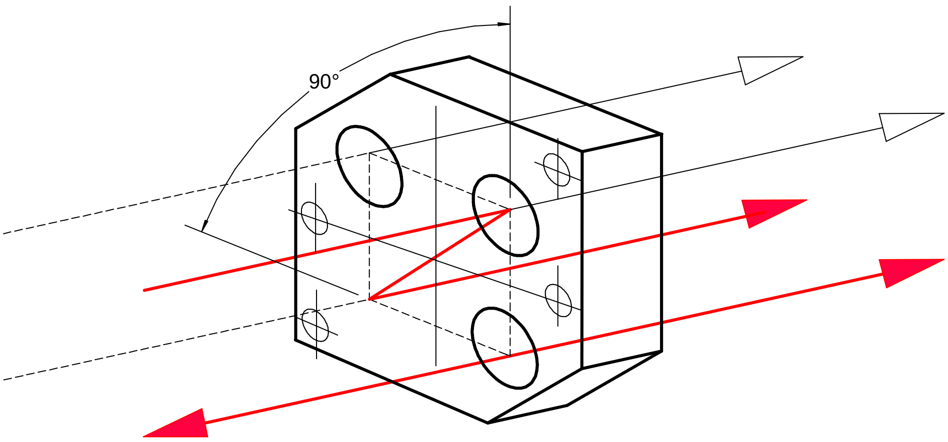


Fig .5: Function of the Beam offset prism 120

Functional description

Angle interferometer

The two light modes emerging from the laser head are seperated by a polarizing beam splitter in the interferometer. The mode deflected by 90° is bent by a 9 0° Beam bender 110 so as to be parallel to the mode that passed the beam splitter unbent.
A double corner reflector consisting of a measuring and a reference reflector retroreflects both partial beams with an offset of 15mm.
Because of the polarizing beam splitter, the measuring reflector only receives light of frequency f1, while the reference reflector only receives light of frequency f2.
With the corner reflector unit at rest, E1 detects the laser´s differential frequency (f1-f2=640MHz), which is equal to the electronic reference signal (E2) detected in the laser head.
If the reflector unit changes its angular position by $\Delta\alpha$ during linear movement, both partial beams are Doppler-Shifted by ±df1 and ±df2, respectively. Accordingly, detector E1 registers a measuring frequency of Δf_{Meas}=(f1±df1) - (f2±df2), depending on which way the measuring reflector is moved.
The two signals detected (E1 and E2) are compared with each other in the high-frequency section of laser interferometer system. The result optained is the frequency shift Δf_{Meas} due to the Doppler effect; this shift is a measure of the displacement Δx of the measuring reflector (Fig. 6).

Angle interferometer 114 and Double corner reflector 115 have a base distance of 40mm.
The configuration described detects angular movements of up to ±8° with a resolution of $1.25 \cdot 10^{-7}$ rad
By angle measurement with Straightness interferometer 128 and Double reflector 160 is base distance b=15mm. The configuration described detects angular movements of up to ±15°. The resolution is $3{,}3 \cdot 10^{-7}$ rad.

If an angle interferometer built up modularly is used, the base distance b is to find out and to input in PC (see software description – chapter E2).

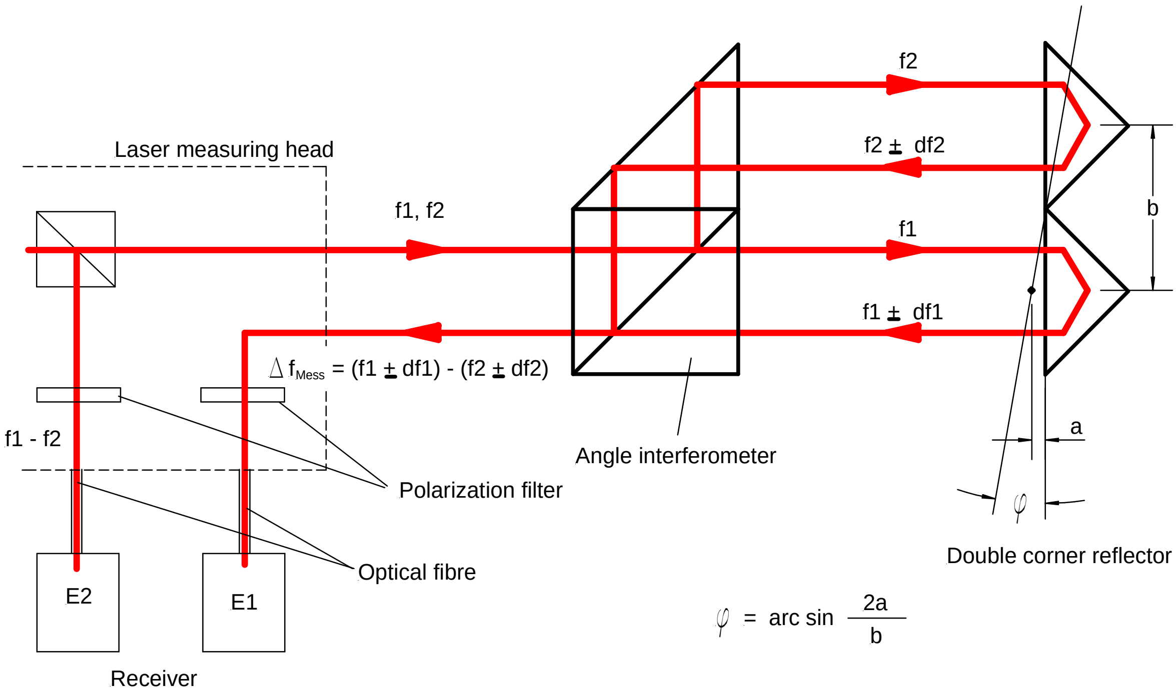


Fig. 6: Function scheme of angle interferometer

Assembly

Fig.7a, 7b and 7c show the optical and mechanical modules and components that make up an angle interferometer.

Angle interferometer (1.25·10^{-7} rad resolution)

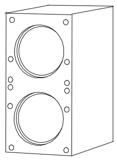
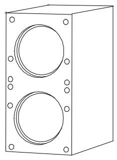
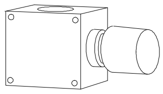
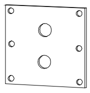
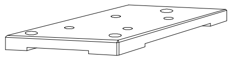
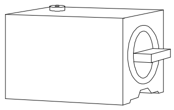
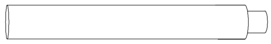
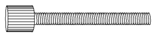
Angle interferometer 114 269302-4015.324		Quantity: 1
Double corner reflector 115 269302-4015.424		Quantity: 1
Clamping fixture 507 269302-4010.325		Quantity: 2
Beam stop plate 516 269302-4014.210		Quantity: 2
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic base 506 260298-3000.128		Quantity: 2
Column 140 260297-9900.128		Quantity: 2
Set of screws 269302-4005.624		Quantity: 1

Fig. 7a: Optical and mechanical components of an angle interferometer

Angle interferometer built up from standard optics (modularly)

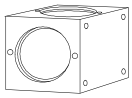
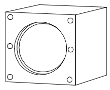
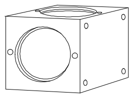
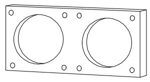
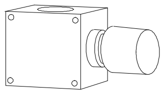
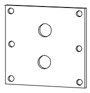
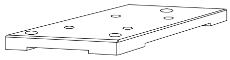
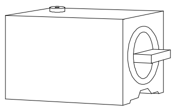
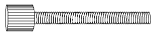
Polarizing beam splitter 101 269302-4010.124		Quantity: 1
Corner reflector 102 269302-4010.224		Quantity: 2
90° beam bender 110 **269302-4011.024**		Quantity: 1
Coupling plate 510 **269302-4014.510**		Quantity: 1
Clamping fixture 507 269302-4010.325		Quantity: 2
Beam stop plate 516 269302-4014.210		Quantity: 2
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic chuck 260298-3000.128		Quantity: 2
Column 140 260297-9900.128		Quantity: 2
Set of screws 269302-4005.624		Quantity: 1

Fig. 7b: Optical and mechanical components of an angle interferometer built up from standard optics

Angle interferometer consisting of Straightness interferometer 128 and double corner reflector 160 (3,3·10^{-7} rad resolution)

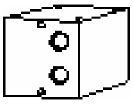
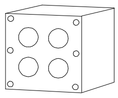
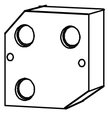
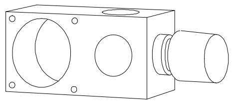
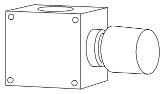
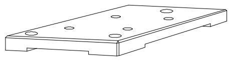
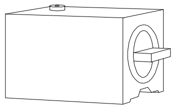
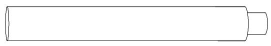
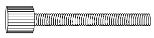
Differential interferometer 128 2693 02- 4012.824		Quantity: 1
Double corner reflector 160 269302- 4016.524		Quantity: 1
Beam offset prism 269302-4008.424		Quantity: 1
Clamping fixture 508 269302-4010.125		Quantity: 2
Clamping fixture 507 269302-4010.325		Quantity: 1
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic chuck 260298-3000.128		Quantity: 2
Column pin 140 260297-9900.128		Quantity: 2
Set of screws 269302-4005.624		Quantity: 1

Fig. 7c: Optical and mechanical components of an angle interferometer built up from Straightness interferometer 128 and Double corner reflector 160

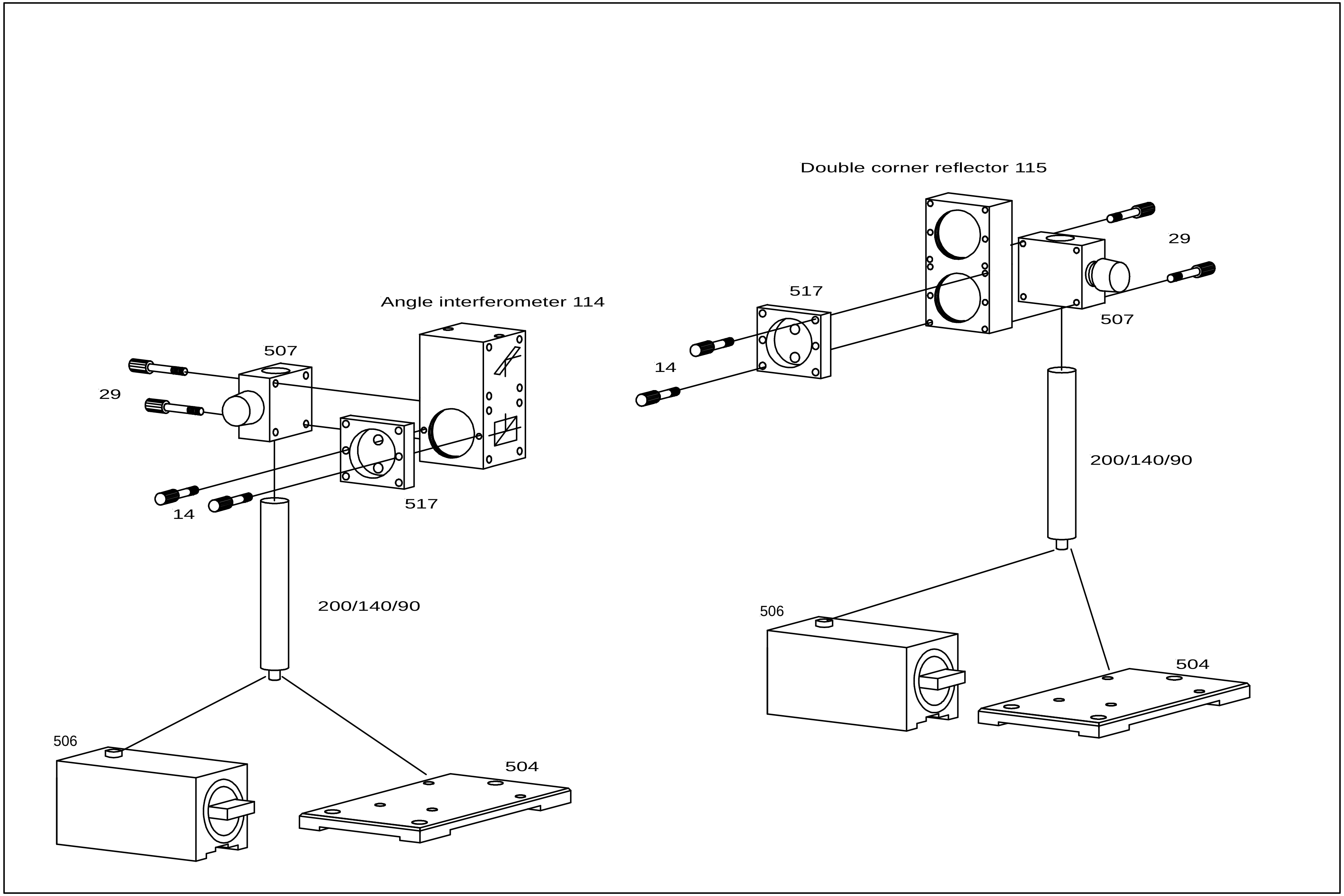


Fig. 8: Assembly of optical components

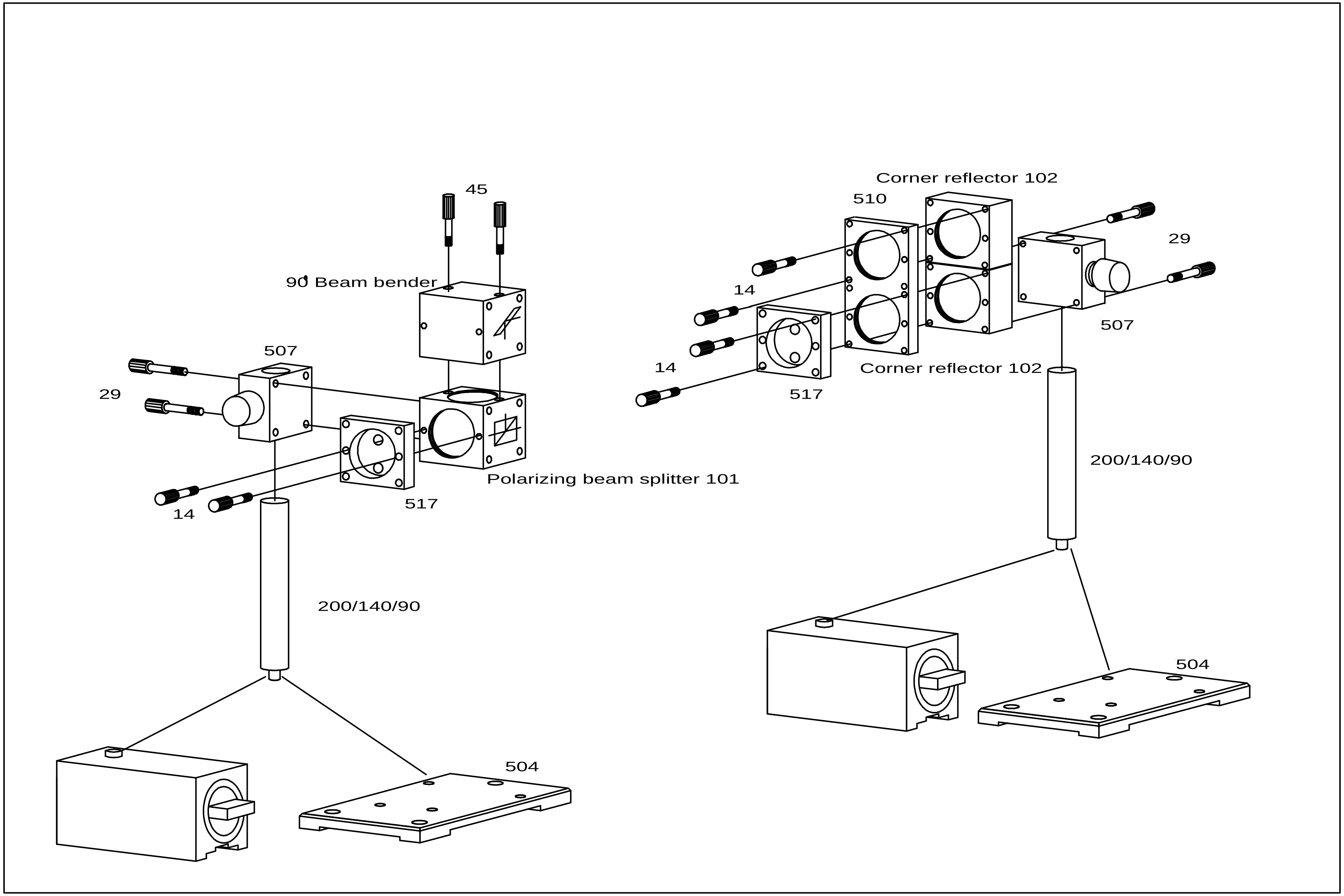


Fig. 9: Assembly of optical components

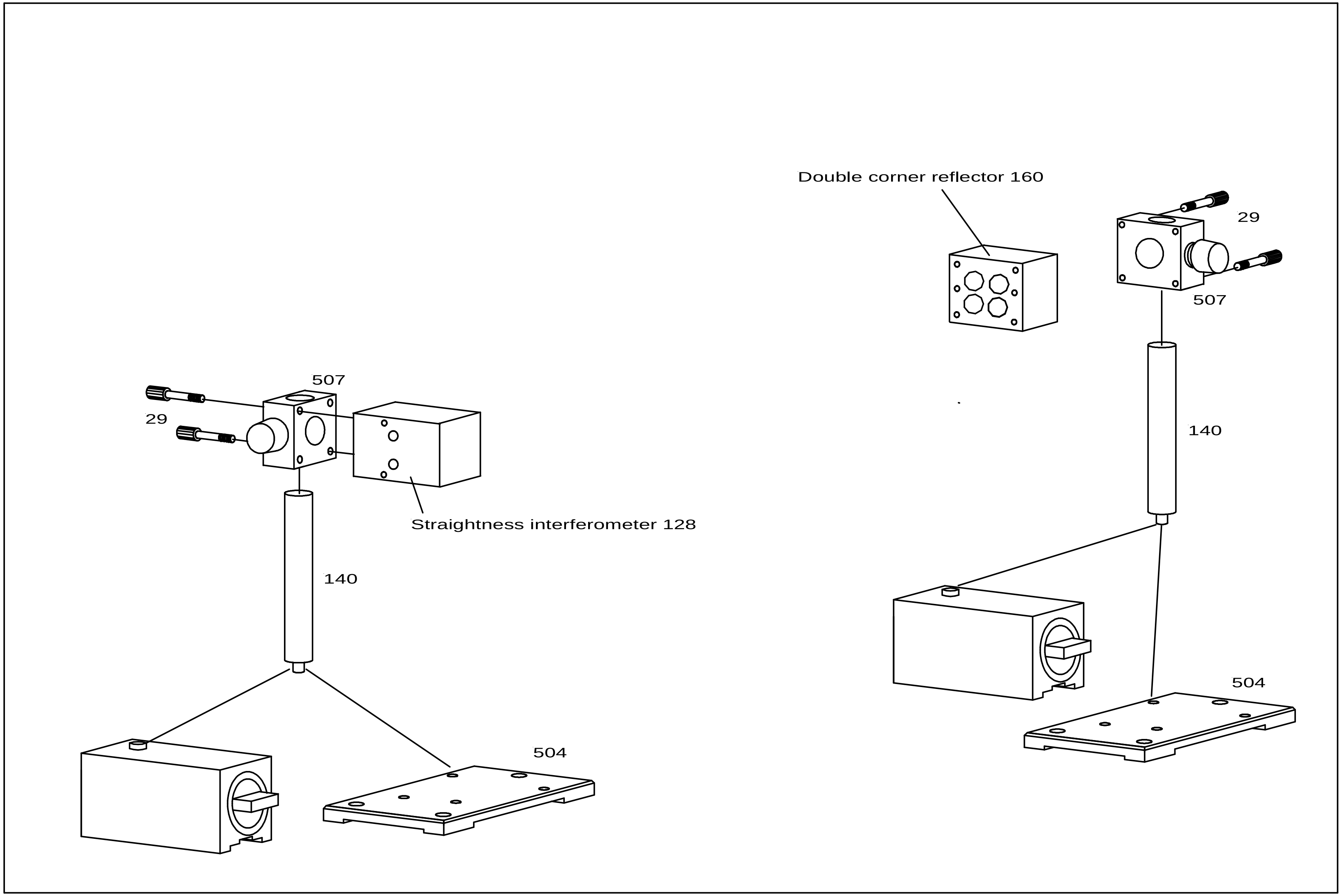


Fig.10a: Angle measurement with Straightness interferometer 128 - horizontal configuration

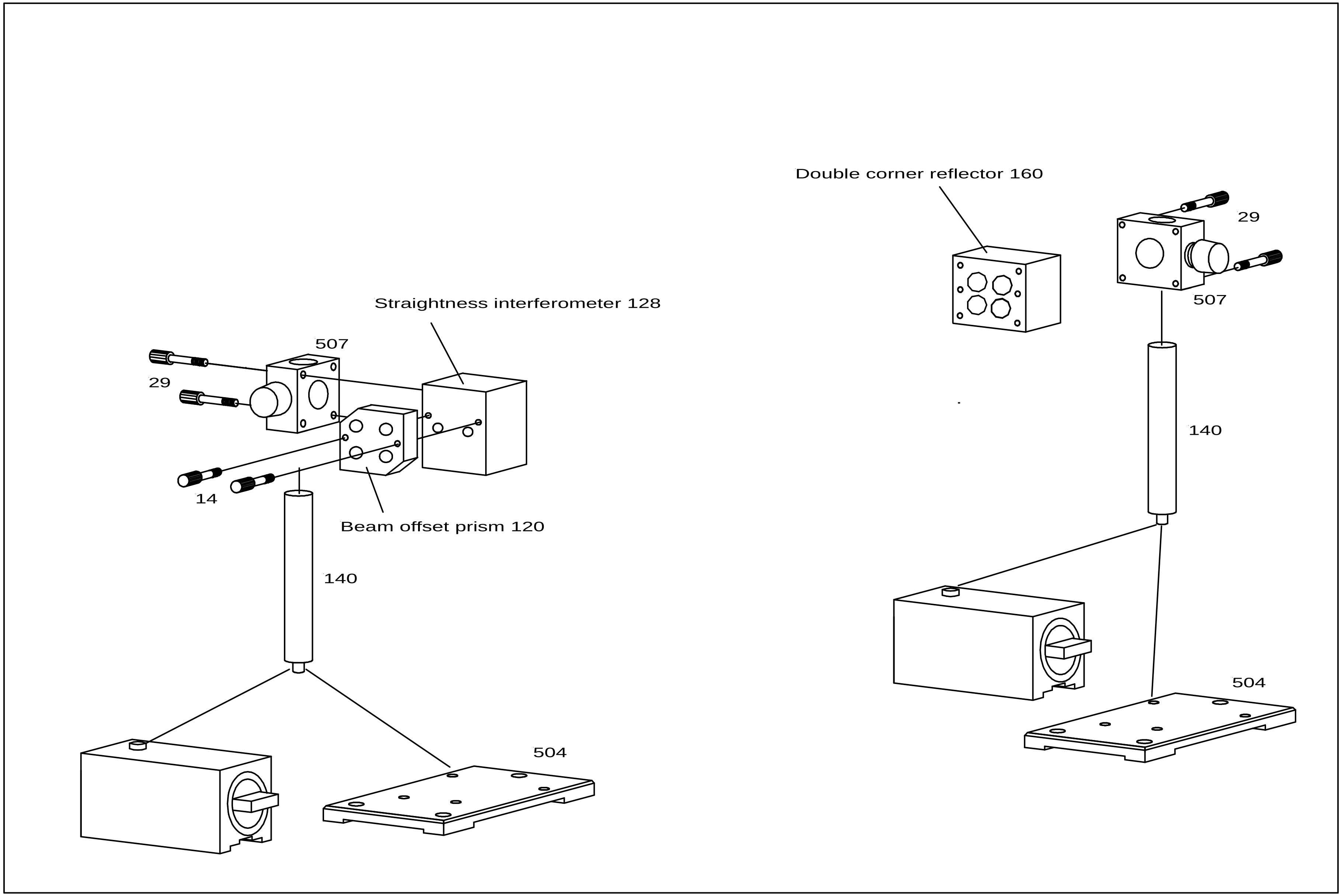


Fig.10b: Angle measurement with Straightness interferometer 128 - vertical configuration

Measurement assembly

The adjustment of the cube corner interferometer for pitch and yaw angle measuring shall be explained at example of the version **Angle interferometer 114** and **Double reflector 115**.
The procedure to the measuring set up is like this one of the cube corner interferometer for position measurement.
The setting-up procedure should follow the sequence of steps described below:

1. Identify the position of the measuring level to the laser beam
2. Find a stationary reference point in line with the axis of movement for building the Angle interferometer 114

> **IMPORTANT:**
> The optical modules must be so located that the beam exit port of the laser head, the stationary point of the angle interferometer and the double corner reflector can be aligned on a line in parallel with the motion axis under test (Fig. 11).

3. Fix the optical modules at the locating points found, wherever possible, in order to reduce measurement errors:

Angle interferometer	stationary reference point (2)
Double corner (measuring) reflector	movable reference point (1)

> **IMPORTANT:**
> Interferometer and corner reflector must have equal distances to the measuring line (h1 = h2 in Fig. 11).

4. Roughly align the laser beam with the optical axis of the installed optical modules.

Tips:

(1) Position the laser head as closely as possible to the interferometer.
(2) Position the Double corner reflector at the most distant point possible from the interferometer.
(3) Check whether the adjustable table is at the centre of its parallel displacement and tilting ranges. ⇨ This is important to ensure sufficient freedom of adjustment both ways during fine alignment of the beam path.

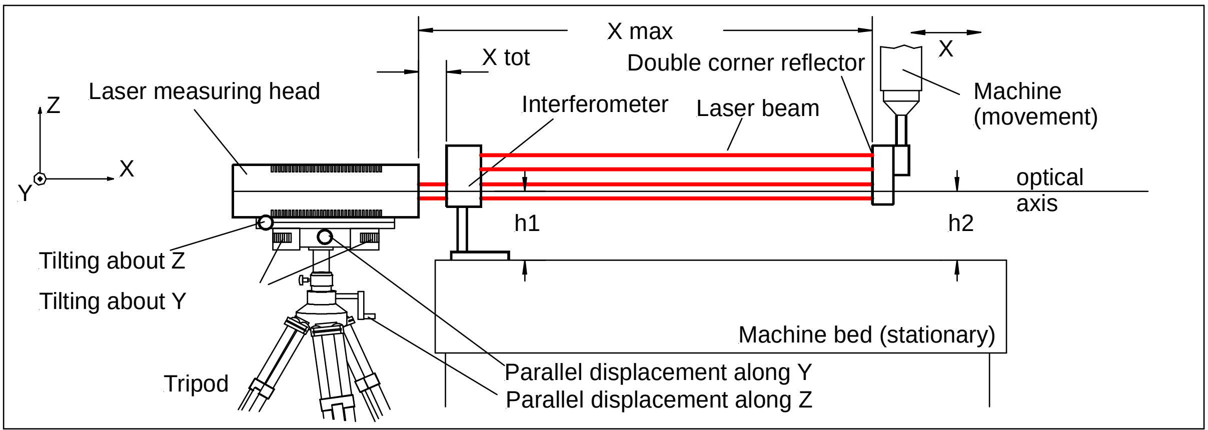


Fig. 11: Measuring setup, optical path

5. Fine alignment of the beam path

Tip:

To facilitate the alignment of the optical path in parallel with the measuring axis, remove the interferometer from the beam path, leaving only the corner reflector. ⇨ That way, only one beam returns to the laser head, which makes it easier to assess the state of alignment.
*Align with the **lower cube corner** of the double reflector.*

A fundamental distinction is made (Fig. 12) between

- positional alignment (Δy, Δz) (parallel displacement along y and z)
- directional alignment (Δϕy, Δϕz) (tilting about y and z)

The ZLM 700 is designed so that both adjustment facilities are provided on the adjustable table / tripod assembly. The merit of this arrangement is that you do not have to constantly alternate between two adjusting locations (laser head - measuring reflector).

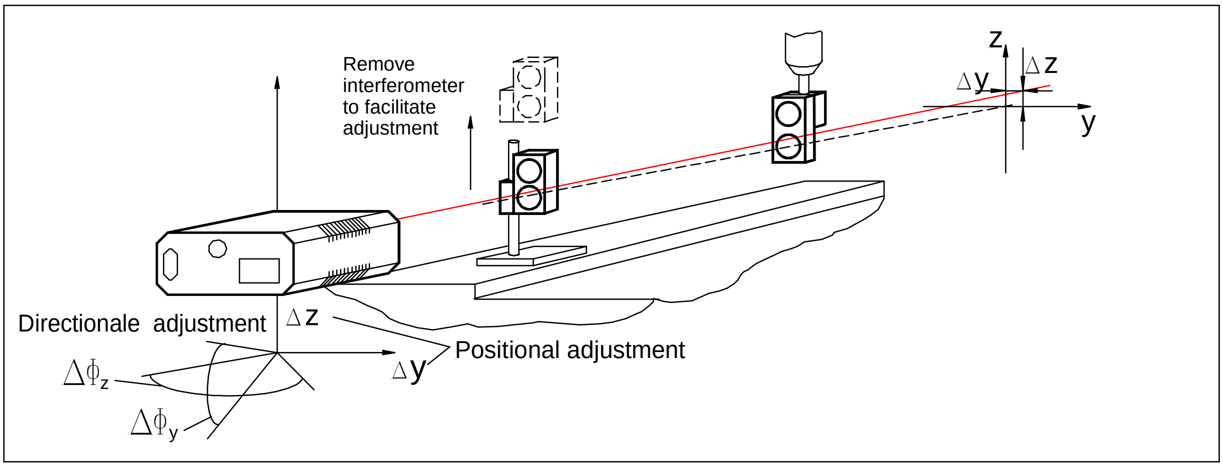


Fig. 12: Alignment of the beam path

The location of the Double cube corner reflector relative to the Angle interferometer is important for both positional and directional alignment (Fig. 13):

Positional alignment, Parallel displacement	⇨	Double cube corner reflector position as closely as possible to the Laser head

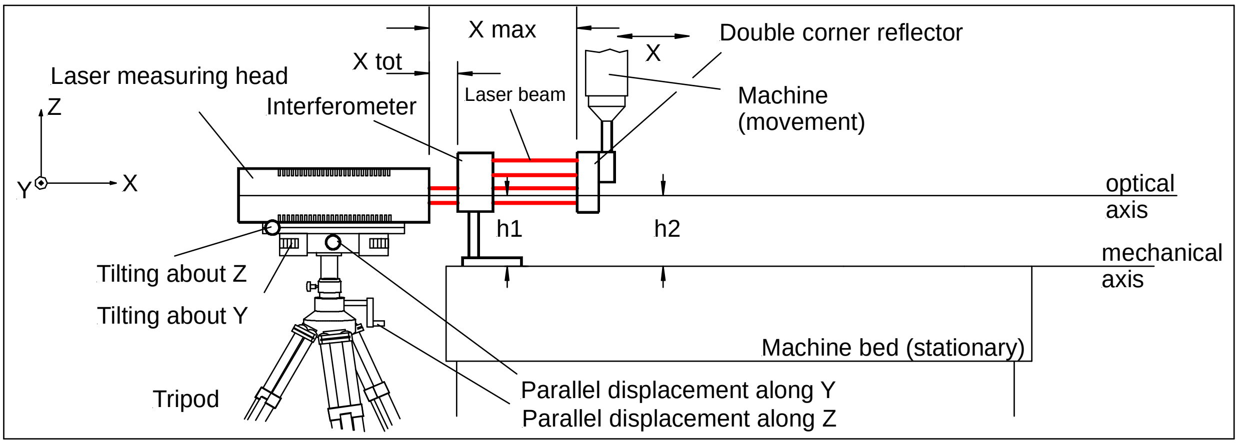


Fig. 13: Positional alignment of the beam path

Directional alignment, tilting Fig. 14	⇨	at the double corner reflector position most distant from the laser head

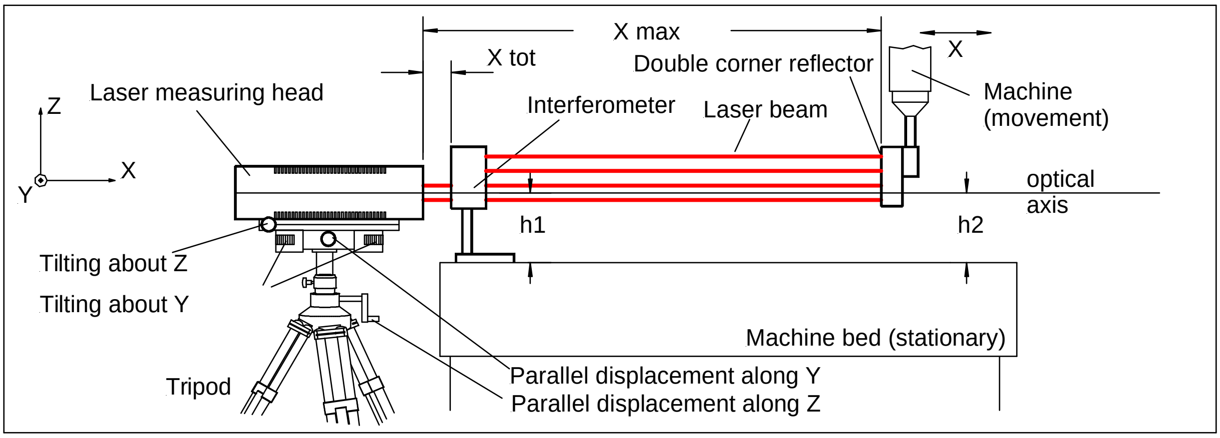
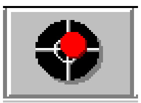


Fig. 14: Directional alignment of the beam path

Adjustment

From these basic principles, the following procedure of aligning the beam path results:

1. Select menu item  in the "Measurement" program routine.
   In this menu item, the powers of the two beams reflected back into the laser head (reference and measuring beam) are represented by two spots on the monitor screen. (With correct aligning procedure, i.e. with the interferometer removed, only the measuring beam is visible.) The screen graph immediately shows the effect of alignment manipulations and thus allows the quality of alignment of the two beams to be checked and optimized.

2. Move Double cube corner to the point most distant from the laser head and fix it there (Fig. 14).
   Adjust the laser beam direction in y and z:

   $\Delta\Phi y$ - Turn the two lateral knurled screws of the adjustable table,
   $\Delta\Phi z$ - Turn the two knurled height adjustment screws of the adjustable table.

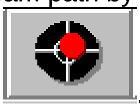
   Align until the reflected beam hits the beam entrance port of the laser head.
   For fine alignment, use the cross-lines shown on the screen.

3. Move the Double cube corner to the point closest to the laser and fix it there (Fig. 13).
   Adjust the laser beam position in y and z:

   Δy - Turn the micrometer screw of the adjustable table to displace the laser in parallel.
   Δz - Turn the height adjustment handwheel of the tripod.

   Align until the reflected beam hits the beam entrance port of the laser head.
   For fine alignment, use the cross-lines shown on the screen.

Repeat steps 2 and 3 alternatingly until no significant change in beam position (relative to the screen cross-lines) can be noticed.
The permanent angular error between the optical and mechanical axes can be seen as the blue moving bar below the cross-lines presentation.

4. After beam path alignment, align the interferometer with the beam path by the following steps (Fig. 15).
   The mechanical mounting height need not be adjusted
   (height is equal to that of the Double corner reflector).
   Effect lateral fine alignment of the beam path by displacing the interferometer, checking the quality of alignment by the screen image .

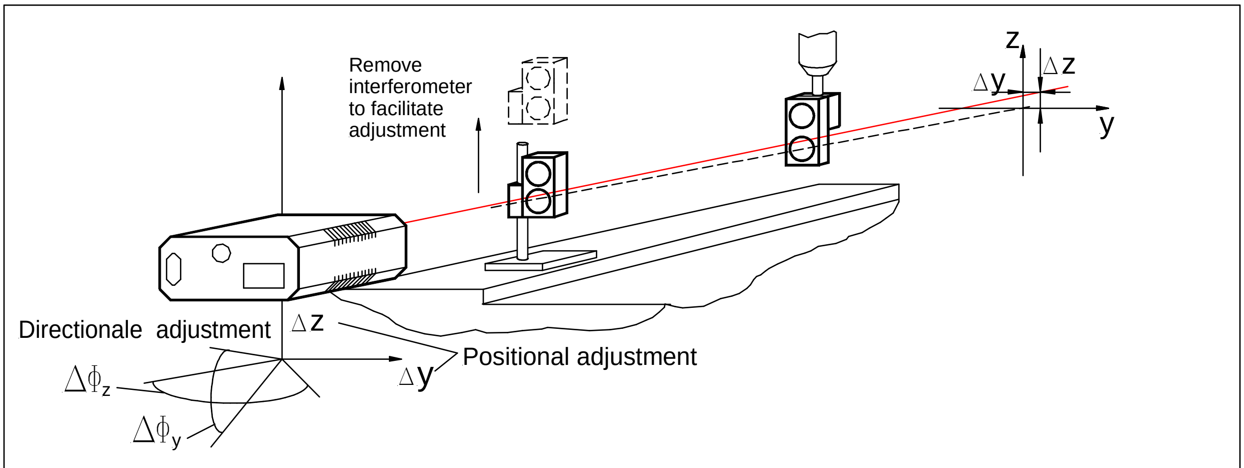


Fig. 15: Aligning the angle interferometer

Note:

The aligning of the interferometer doesn't influence the adjusted beam path of the Double cube corner reflector.

IMPORTANT:

Pay attention to the **same local situation** of the points of measuring and reference beam in the cross-lines.
(importantly for perfect interferenc signal education)

Aligning the interferometer completes the alignment of the setup, which is now ready for measurement (see the Software Manual).

C Interferometer with cube corner reflectors for the angle measuring

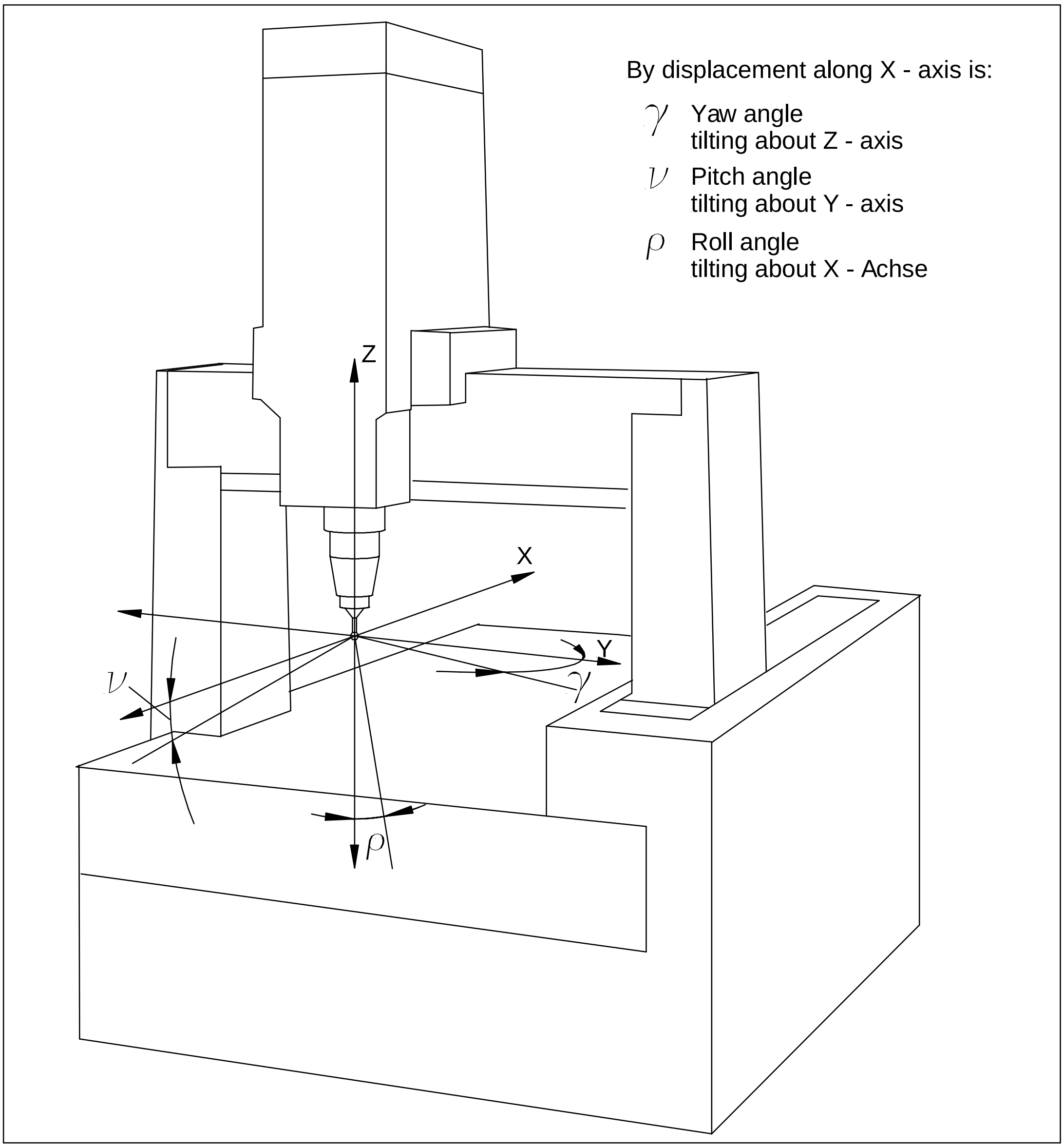


Fig. 1: Tilt angle at a coordinate measuring machine

To the detection of yaw and pitch angle errors of machine tools, coordinate measuring machines etc. as well as for the solution of other angle measurement problems special angle interferometers can be used. These consist of the optics modules:

1 Angle interferometer 114	***269302-4015.324***
1 Double corner reflector 115	***269302-4015.424***

If a position or distance measuring was already carried out, the construction can be converted by simple exchange of the optics modules without long adjustment of angle measurement. The parallelism of the angle interferometer makes it possible to measure angles on guide way lengths to 20 m.

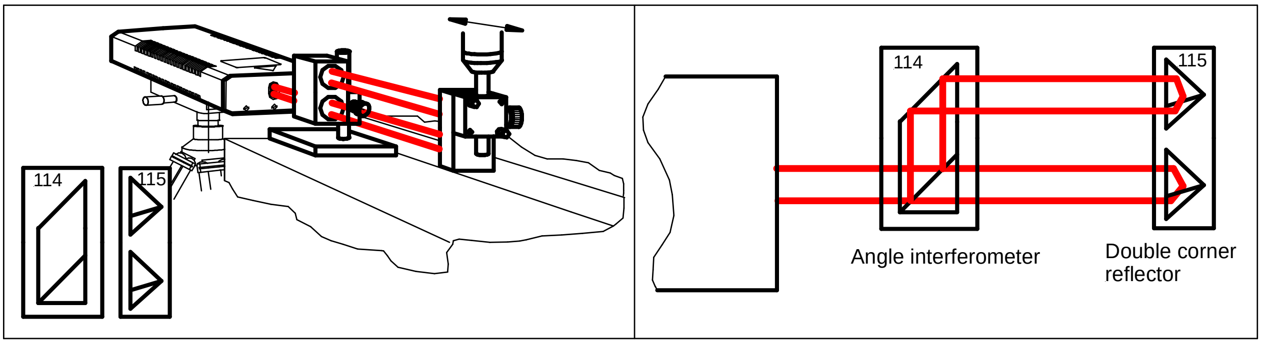


Fig. 2: Optical arrangement: angle interferometer for the pitch angle measuring
(for the yaw angle measuring: turn angle interferometer and double corner reflector by 90°)

For special measurement tasks there is the possibility to realize the construction of an angle interferometer with the standard optics modules (Fig. 3).

<u>Angle interferometer with standard optical modules:</u>

1 Polarizing beam splitter 101 ***269302-4010.124***
1 90° Beam bender 110 ***269302-4011.024***
2 Cube corner reflector 102 ***269302-4010.224***

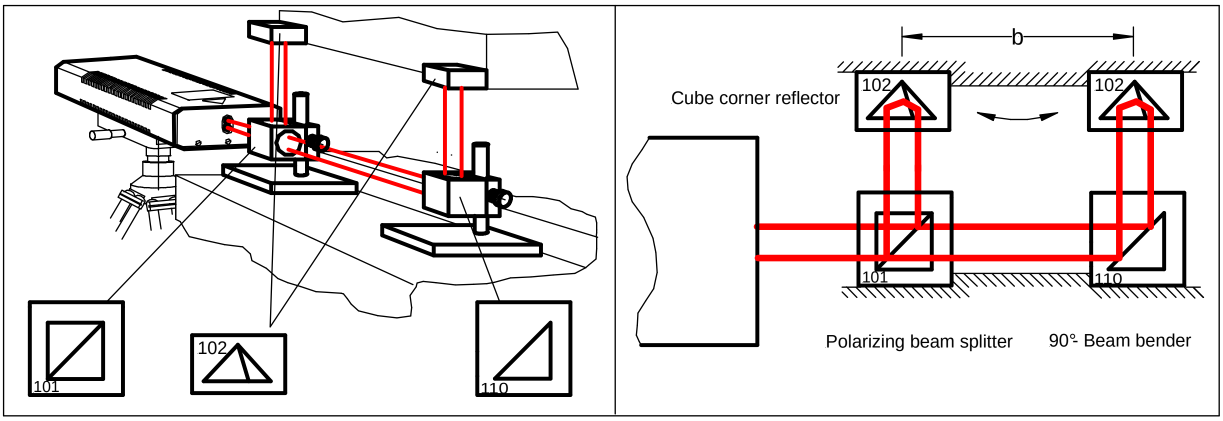


Fig. 3: Optical arrangement: angle interferometer with the standard optics modules

<u>Angle interferometer with straightness optical modules:</u>

1 Straightness interferometer 128 ***269302-4012.824***
1 Double corner reflector 160 ***269302-4014.424***
if necessary
1 Beam offset prism120 ***269302-4008.424***

With Straightness interferometer 128 and Double corner reflector 160 is it possible to make angle measurements.

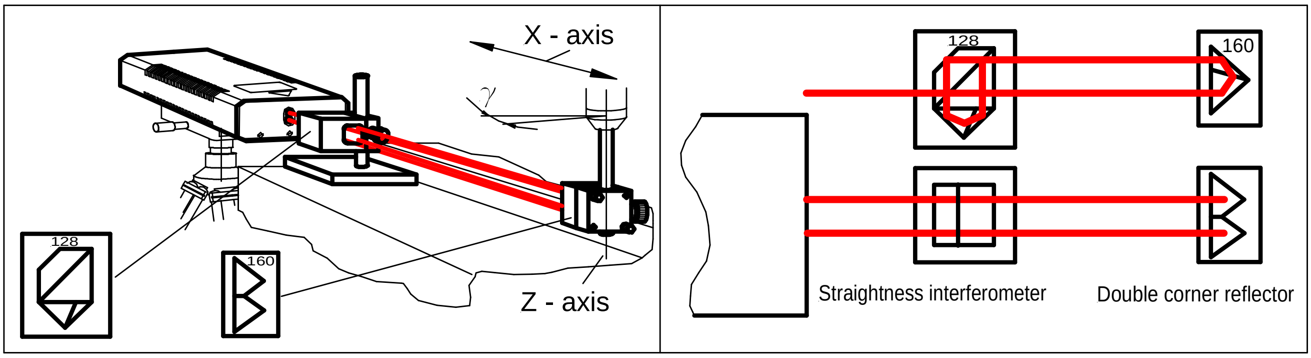


Fig. 4: Optical arrangement: angle interferometer (Straightness interferometer 128 with cube corner reflector 160) for the yaw angle measuring
(for the pitch angle measuring: turn angle interferometer and double corner reflector by 90°)

Fig. 4 shows the optical arrangement of yaw angle measurement with straightness interferometer 128 and double corner reflector 160. The measuring of the pitch angle is also possible with this interferometer variant. Straightness interferometer and Cube corner reflector must be turned by 90° for assembling.

The beam offset prism 120 is to install in addition, so that the beam coming back off the interferometer can enter the laser measuring head again.
In beam offset prism taking place a beam redirection about diagonal and in order that a shifting to 90° (Fig. 5).

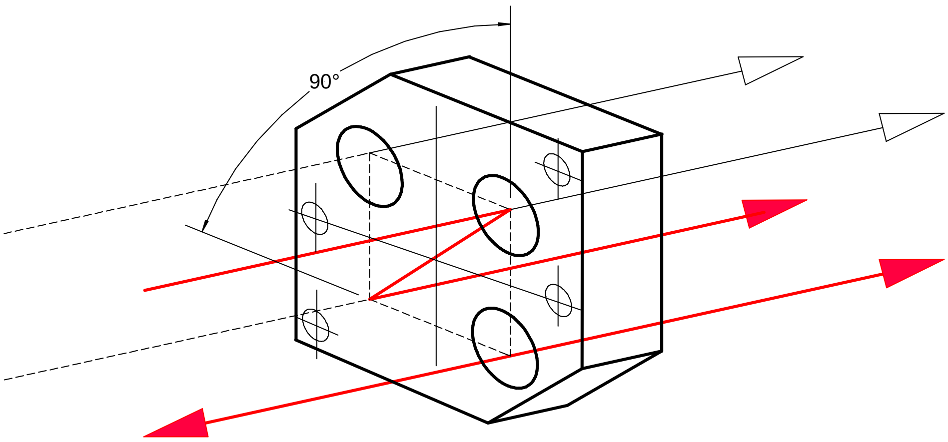


Fig .5: Function of the Beam offset prism 120

Functional description

Angle interferometer

The two light modes emerging from the laser head are seperated by a polarizing beam splitter in the interferometer. The mode deflected by 90° is bent by a 90° Beam bender 110 so as to be parallel to the mode that passed the beam splitter unbent.
A double corner reflector consisting of a measuring and a reference reflector retroreflects both partial beams with an offset of 15mm.
Because of the polarizing beam splitter, the measuring reflector only receives light of frequency f1, while the reference reflector only receives light of frequency f2.
With the corner reflector unit at rest, E1 detects the laser´s differential frequency (f1-f2=640MHz), which is equal to the electronic reference signal (E2) detected in the laser head.
If the reflector unit changes its angular position by $\Delta\alpha$ during linear movement, both partial beams are Doppler-Shifted by ±df1 and ±df2, respectively. Accordingly, detector E1 registers a measuring frequency of Δf_{Meas}=(f1±df1) - (f2±df2), depending on which way the measuring reflector is moved.
The two signals detected (E1 and E2) are compared with each other in the high-frequency section of laser interferometer system. The result optained is the frequency shift Δf_{Meas} due to the Doppler effect; this shift is a measure of the displacement Δx of the measuring reflector (Fig. 6).

Angle interferometer 114 and Double corner reflector 115 have a base distance of 40mm.
The configuration described detects angular movements of up to ±8° with a resolution of $1.25 \cdot 10^{-7}$ rad
By angle measurement with Straightness interferometer 128 and Double reflector 160 is base distance b=15mm. The configuration described detects angular movements of up to ±15°. The resolution is $3,3 \cdot 10^{-7}$ rad.

If an angle interferometer built up modularly is used, the base distance b is to find out and to input in PC (see software description – chapter E2).

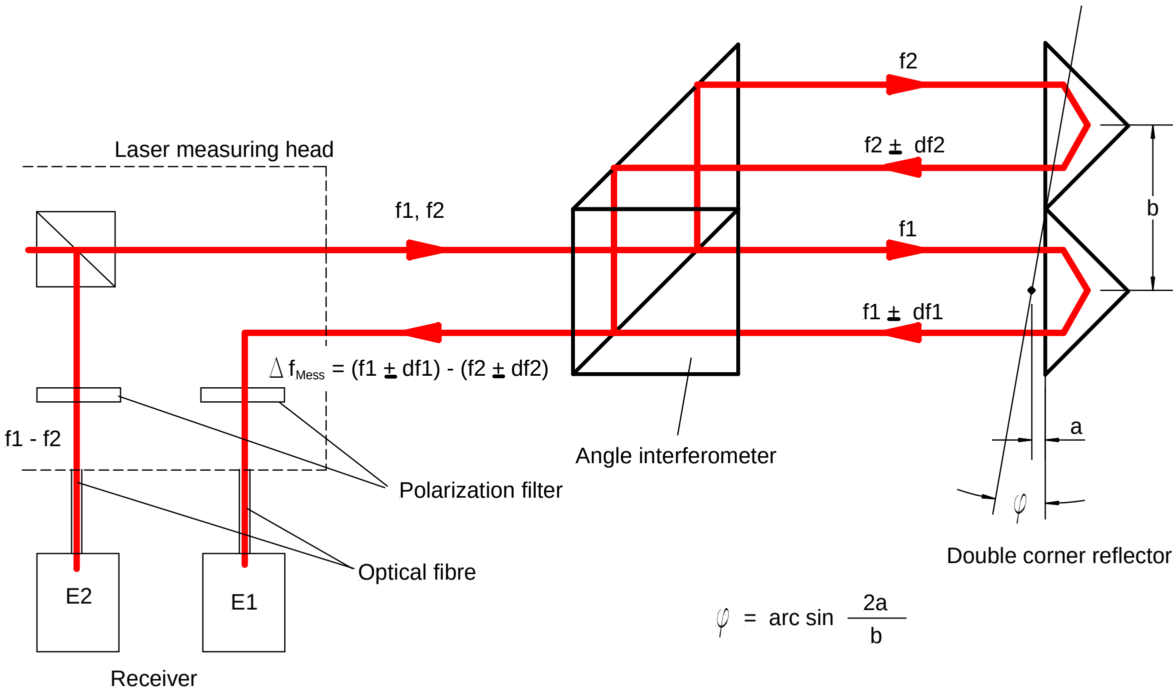


Fig. 6: Function scheme of angle interferometer

Assembly

Fig.7a, 7b and 7c show the optical and mechanical modules and components that make up an angle interferometer.

Angle interferometer (1.25·10^{-7} rad resolution)

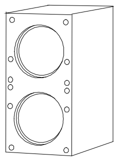
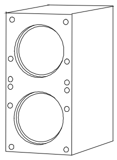
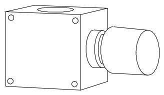
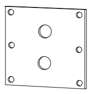
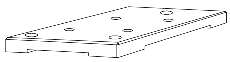
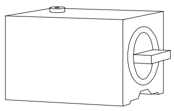
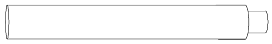
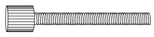
Angle interferometer 114 269302-4015.324		Quantity: 1
Double corner reflector 115 269302-4015.424		Quantity: 1
Clamping fixture 507 269302-4010.325		Quantity: 2
Beam stop plate 516 269302-4014.210		Quantity: 2
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic base 506 260298-3000.128		Quantity: 2
Column 140 260297-9900.128		Quantity: 2
Set of screws 269302-4005.624		Quantity: 1

Fig. 7a: Optical and mechanical components of an angle interferometer

Angle interferometer built up from standard optics (modularly)

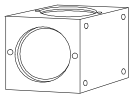
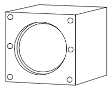
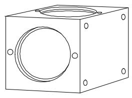
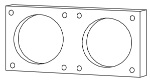
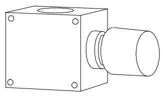
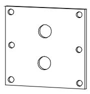
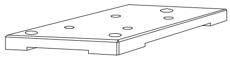
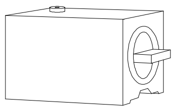
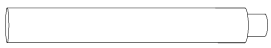
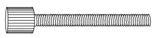
Polarizing beam splitter 101 269302-4010.124		Quantity: 1
Corner reflector 102 269302-4010.224		Quantity: 2
90° beam bender 110 **269302-4011.024**		Quantity: 1
Coupling plate 510 **269302-4014.510**		Quantity: 1
Clamping fixture 507 269302-4010.325		Quantity: 2
Beam stop plate 516 269302-4014.210		Quantity: 2
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic chuck 260298-3000.128		Quantity: 2
Column 140 260297-9900.128		Quantity: 2
Set of screws 269302-4005.624		Quantity: 1

Fig. 7b: Optical and mechanical components of an angle interferometer built up from standard optics

Angle interferometer consisting of Straightness interferometer 128 and double corner reflector 160 (3,3·10^{-7} rad resolution)

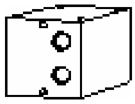
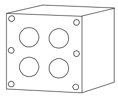
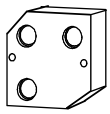
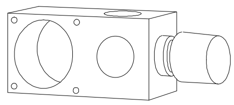
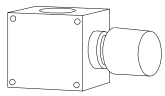
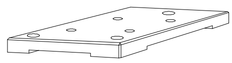
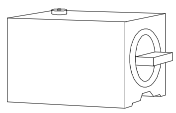
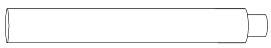
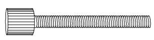
Differential interferometer 128 2693 02- 4012.824		Quantity: 1
Double corner reflector 160 269302- 4016.524		Quantity: 1
Beam offset prism 269302-4008.424		Quantity: 1
Clamping fixture 508 269302-4010.125		Quantity: 2
Clamping fixture 507 269302-4010.325		Quantity: 1
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic chuck 260298-3000.128		Quantity: 2
Column pin 140 260297-9900.128		Quantity: 2
Set of screws 269302-4005.624		Quantity: 1

Fig. 7c: Optical and mechanical components of an angle interferometer built up from Straightness interferometer 128 and Double corner reflector 160

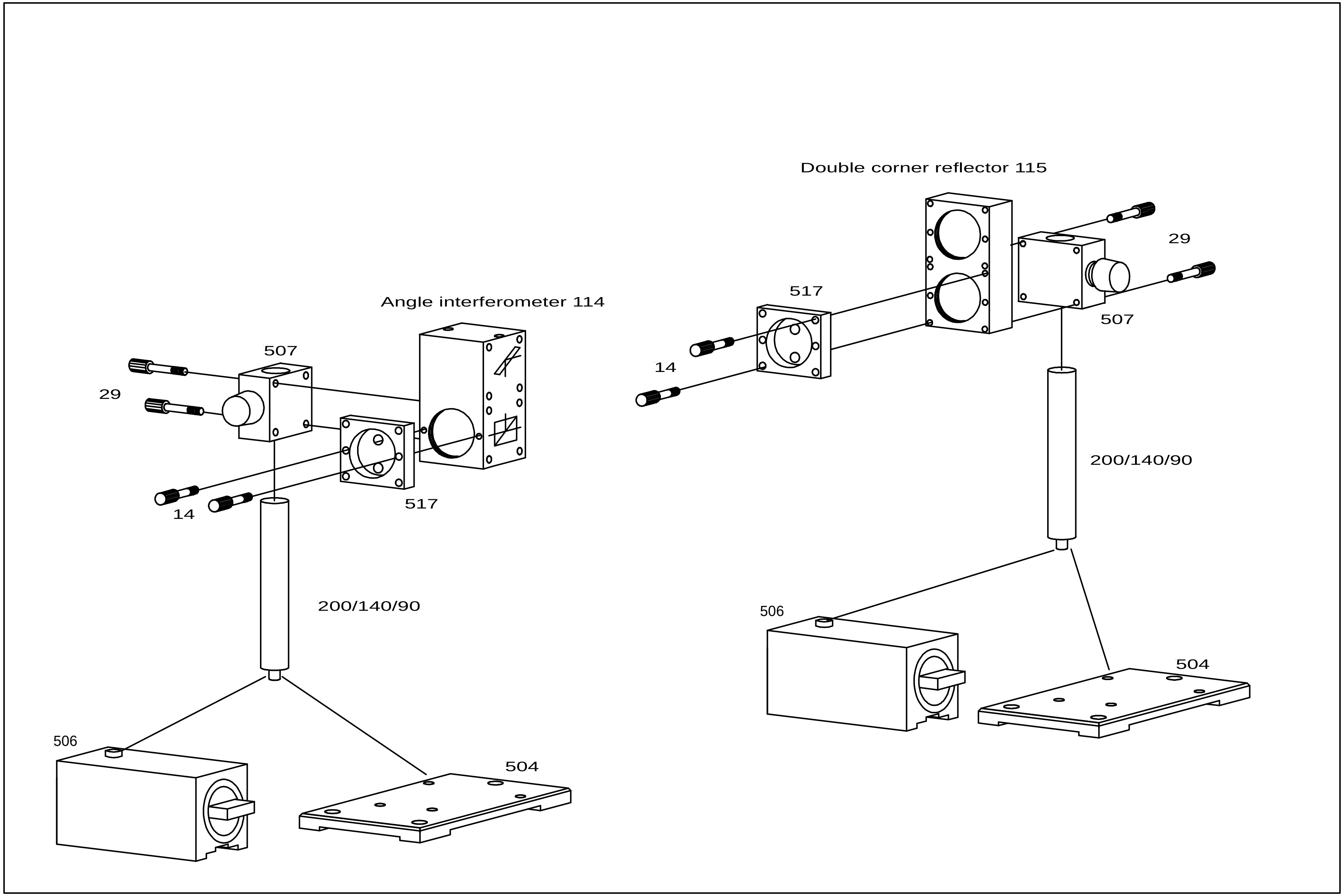


Fig. 8: Assembly of optical components

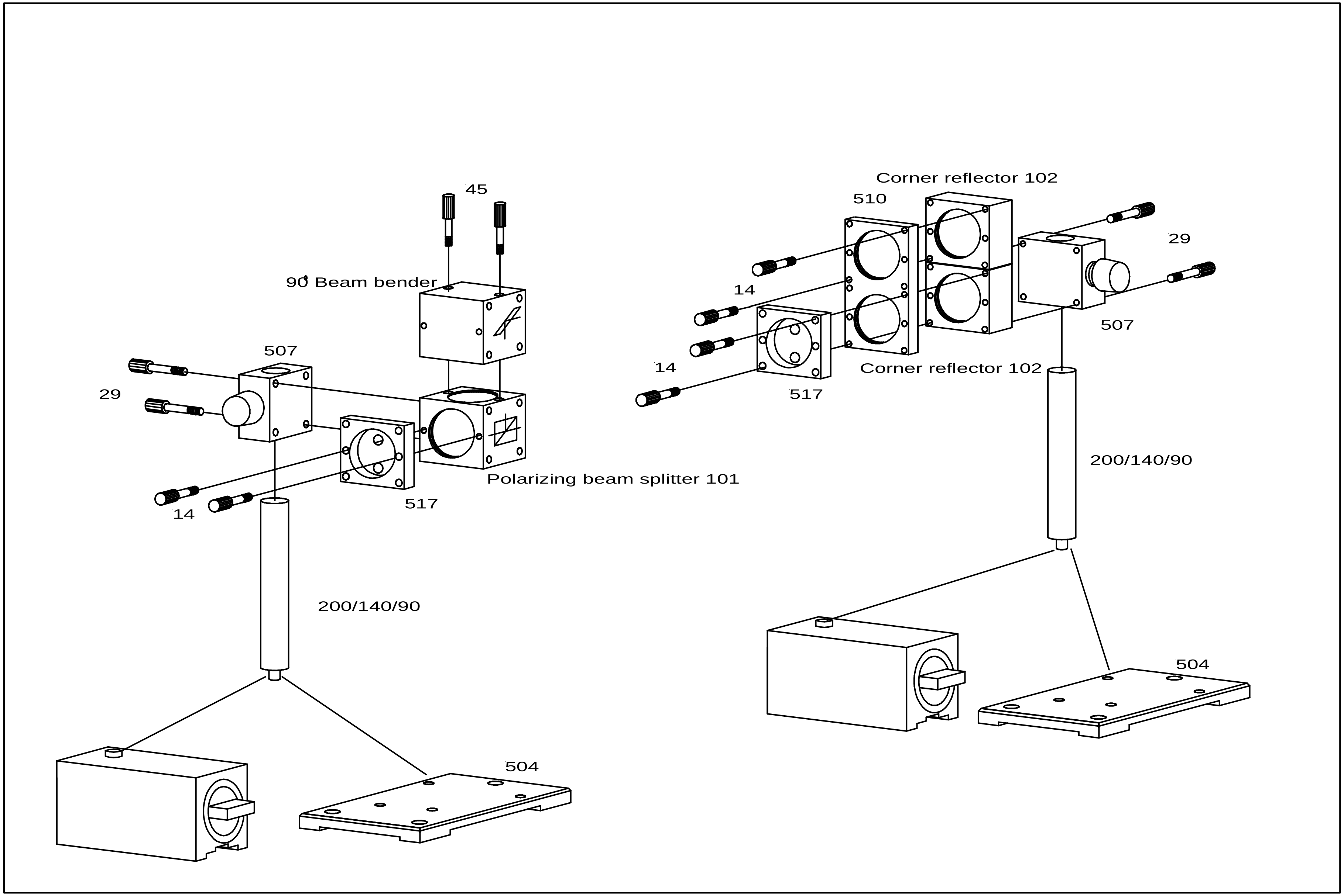


Fig. 9: Assembly of optical components

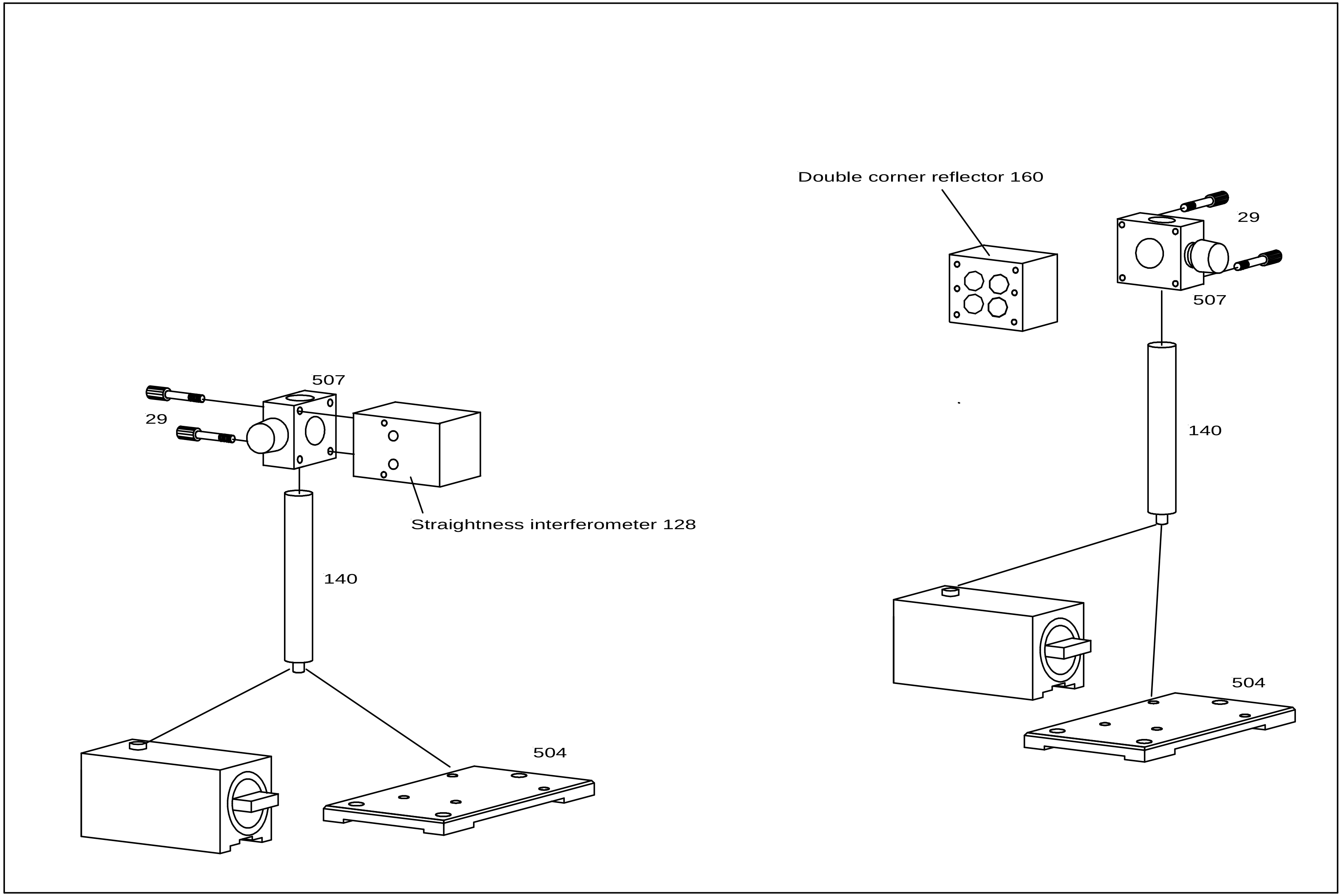


Fig.10a: Angle measurement with Straightness interferometer 128 - horizontal configuration

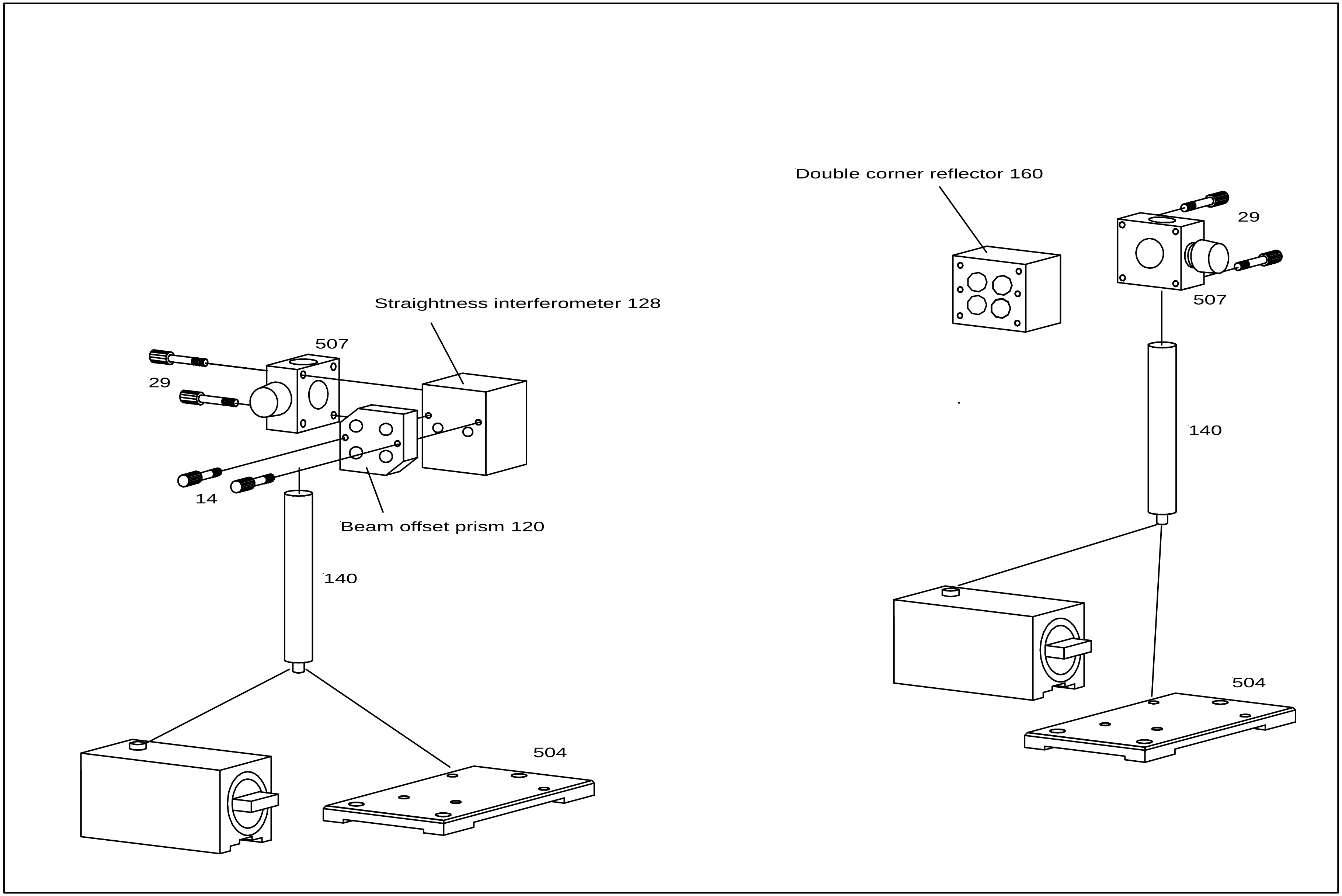


Fig.10b: Angle measurement with Straightness interferometer 128 - vertical configuration

Measurement assembly

The adjustment of the cube corner interferometer for pitch and yaw angle measuring shall be explained at example of the version **Angle interferometer 114** and **Double reflector 115**.
The procedure to the measuring set up is like this one of the cube corner interferometer for position measurement.
The setting-up procedure should follow the sequence of steps described below:

1. Identify the position of the measuring level to the laser beam

2. Find a stationary reference point in line with the axis of movement for building the Angle interferometer 114

IMPORTANT:
The optical modules must be so located that the beam exit port of the laser head, the stationary point of the angle interferometer and the double corner reflector can be aligned on a line in parallel with the motion axis under test (Fig. 11).

3. Fix the optical modules at the locating points found, wherever possible, in order to reduce measurement errors:

Angle interferometer	stationary reference point (2)
Double corner (measuring) reflector	movable reference point (1)

IMPORTANT:
Interferometer and corner reflector must have equal distances to the measuring line (h1 = h2 in Fig. 11).

4. Roughly align the laser beam with the optical axis of the installed optical modules.

Tips:
(1) Position the laser head as closely as possible to the interferometer.
(2) Position the Double corner reflector at the most distant point possible from the interferometer.
(3) Check whether the adjustable table is at the centre of its parallel displacement and tilting ranges. ⇨ This is important to ensure sufficient freedom of adjustment both ways during fine alignment of the beam path.

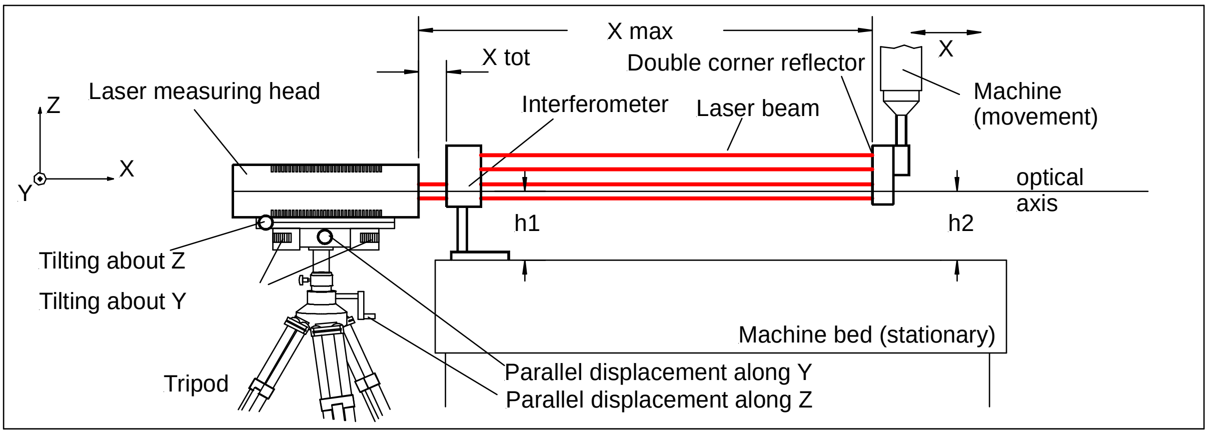


Fig. 11: Measuring setup, optical path

5. Fine alignment of the beam path

Tip:

To facilitate the alignment of the optical path in parallel with the measuring axis, remove the interferometer from the beam path, leaving only the corner reflector. ⇨ That way, only one beam returns to the laser head, which makes it easier to assess the state of alignment.
*Align with the **lower cube corner** of the double reflector.*

A fundamental distinction is made (Fig. 12) between

- positional alignment (Δy, Δz) — (parallel displacement along y and z)
- directional alignment ($\Delta\phi y$, $\Delta\phi z$) — (tilting about y and z)

The ZLM 700 is designed so that both adjustment facilities are provided on the adjustable table / tripod assembly. The merit of this arrangement is that you do not have to constantly alternate between two adjusting locations (laser head - measuring reflector).

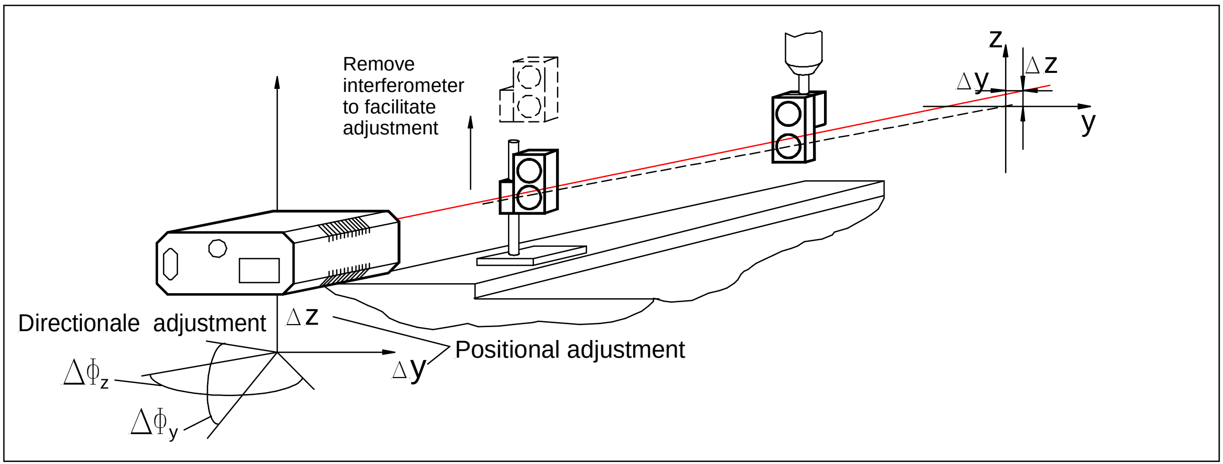


Fig. 12: Alignment of the beam path

The location of the Double cube corner reflector relative to the Angle interferometer is important for both positional and directional alignment (Fig. 13):

Positional alignment, Parallel displacement ⇨ Double cube corner reflector position as closely as possible to the Laser head

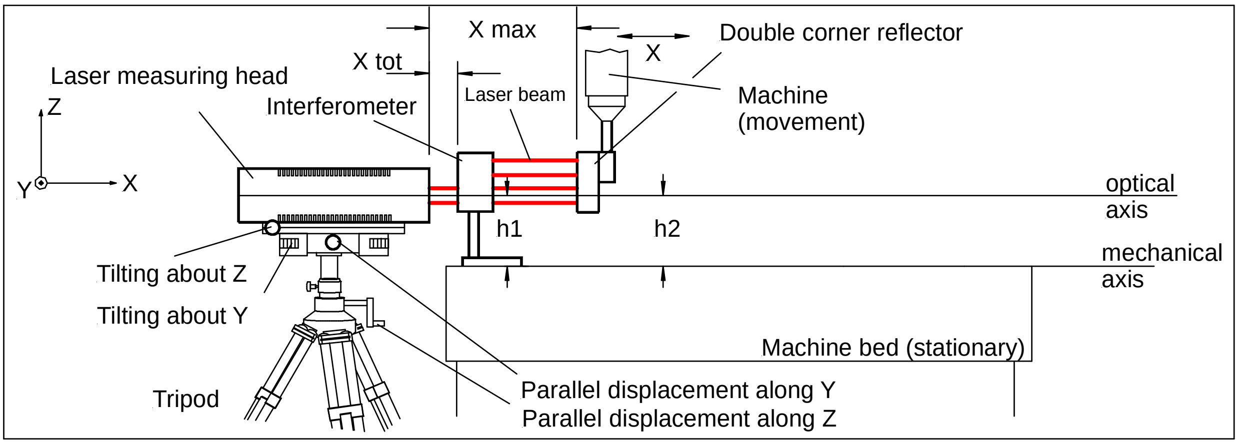


Fig. 13: Positional alignment of the beam path

Directional alignment, tilting ⇨ at the double corner reflector position
Fig. 14 most distant from the laser head

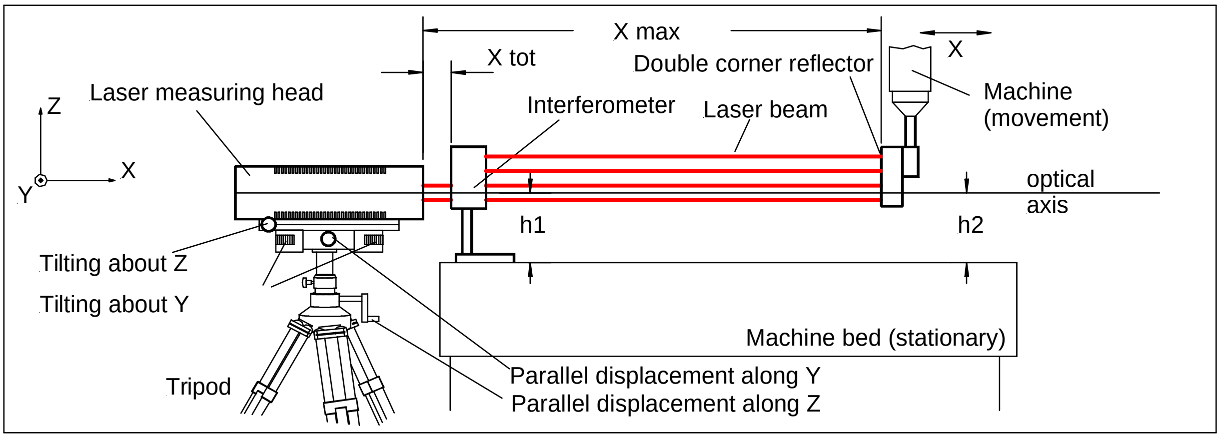
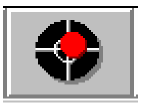


Fig. 14: Directional alignment of the beam path

Adjustment

From these basic principles, the following procedure of aligning the beam path results:

1. Select menu item  in the "Measurement" program routine.
   In this menu item, the powers of the two beams reflected back into the laser head (reference and measuring beam) are represented by two spots on the monitor screen. (With correct aligning procedure, i.e. with the interferometer removed, only the measuring beam is visible.) The screen graph immediately shows the effect of alignment manipulations and thus allows the quality of alignment of the two beams to be checked and optimized.

2. Move Double cube corner to the point most distant from the laser head and fix it there (Fig. 14).
   Adjust the laser beam direction in y and z:

   ΔΦy - Turn the two lateral knurled screws of the adjustable table,
   ΔΦz - Turn the two knurled height adjustment screws of the adjustable table.

   Align until the reflected beam hits the beam entrance port of the laser head.
   For fine alignment, use the cross-lines shown on the screen.

3. Move the Double cube corner to the point closest to the laser and fix it there (Fig. 13).
   Adjust the laser beam position in y and z:

   Δy - Turn the micrometer screw of the adjustable table to displace the laser in parallel.
   Δz - Turn the height adjustment handwheel of the tripod.

   Align until the reflected beam hits the beam entrance port of the laser head.
   For fine alignment, use the cross-lines shown on the screen.

Repeat steps 2 and 3 alternatingly until no significant change in beam position (relative to the screen cross-lines) can be noticed.
The permanent angular error between the optical and mechanical axes can be seen as the blue moving bar below the cross-lines presentation.

4. After beam path alignment, align the interferometer with the beam path by the following steps (Fig. 15).
   The mechanical mounting height need not be adjusted
   (height is equal to that of the Double corner reflector).
   Effect lateral fine alignment of the beam path by displacing the interferometer, checking the quality of alignment by the screen image .

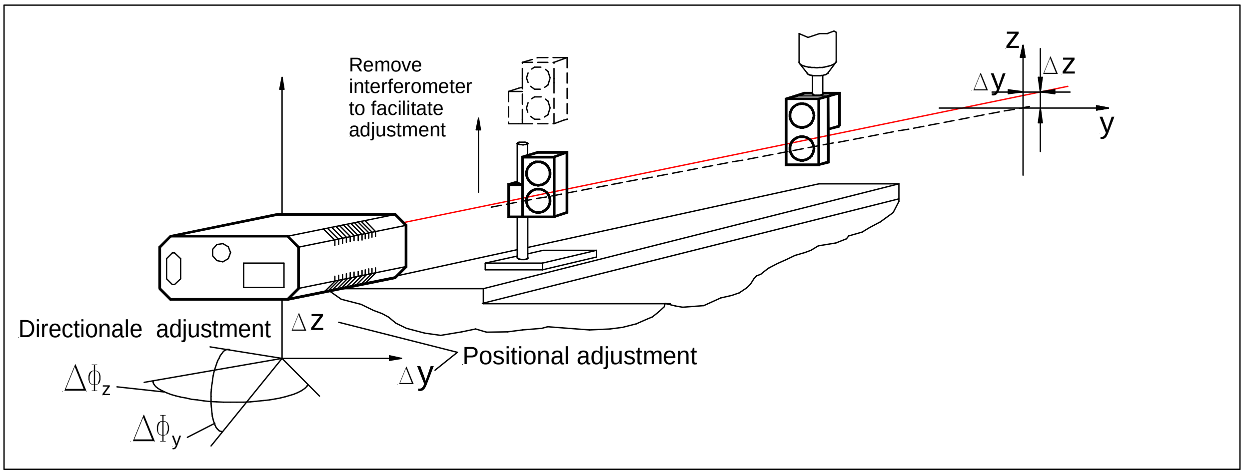


Fig. 15: Aligning the angle interferometer

Note:

The aligning of the interferometer doesn't influence the adjusted beam path of the Double cube corner reflector.

IMPORTANT:

Pay attention to the **same local situation** of the points of measuring and reference beam in the cross-lines.
(importantly for perfect interferenc signal education)

Aligning the interferometer completes the alignment of the setup, which is now ready for measurement (see the Software Manual).

D Interferometer with cube corner reflectors for the angle measuring

Angle interferometer for the roll angle measuring

Certain measuring assignments are not resolvable with cube corner reflectors. This is always then the case when the movement of the measuring object isn't carried out in the direction of the laser beam but lateral to this. An example of it is the rolling angle measuring.
In such cases the area of reflection of a plane mirror is this flatness normal, - the measuring refers to it.
For attainable measuring accuracy is important the grade of flatness of the measuring mirror causing systematic faults.

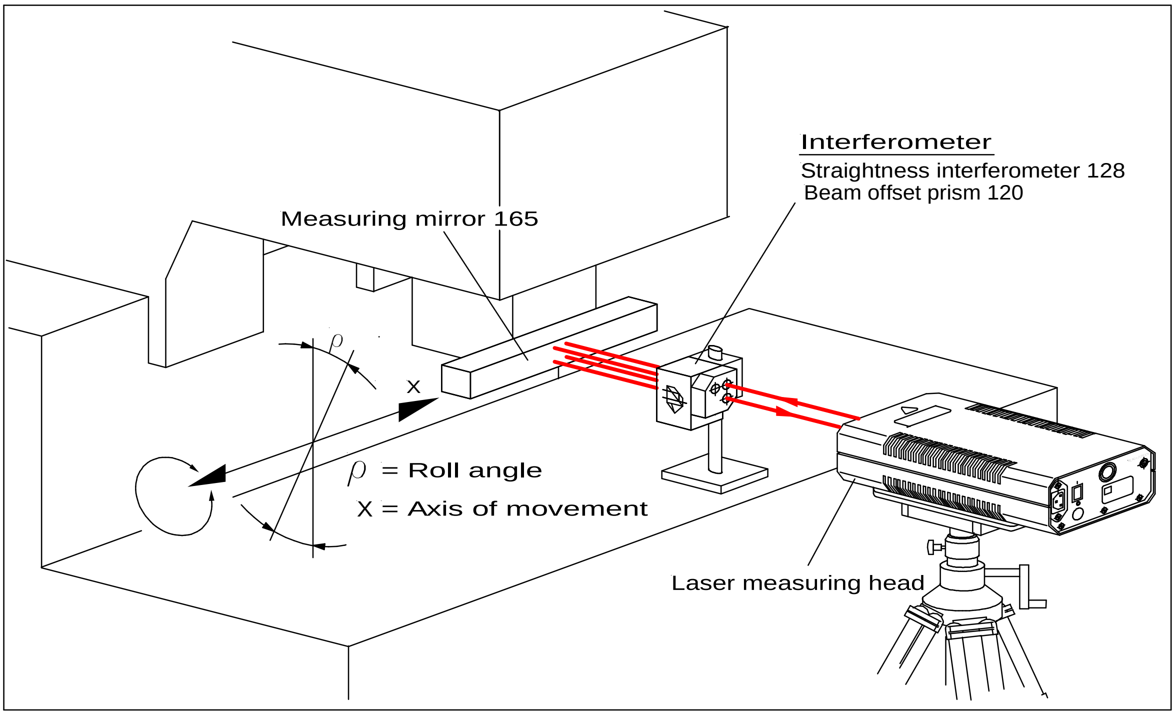


Fig. 1: Roll angle measuring with Straightness interferometer 128 and Measuring mirror 165

For roll angle measurement is necessary:

1 Straightness interferometer 128 ***269302-4012.824***
1 Measuring mirror 165 ***269302-4016.524***
and additional, ever after in which direction is measured the tilting
1 Beam offset prism 120 ***269302-4008.424***

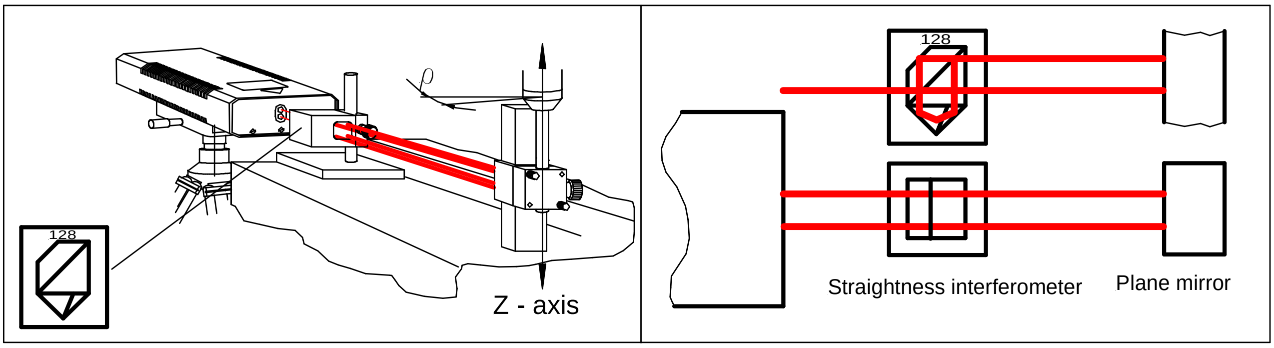


Fig. 2: Optical arrangement: angle interferometer for the roll angle measuring

Fig. 2 shows the construction of the rolling angle measuring in vertical movement direction. The Beam offset prism is required in the case of horizontal movement direction (Fig. 2 and Fig. 4a), da der zum Lasermesskopf zurückkehrende Strahl um 90° gedreht werden muss.

Assembly

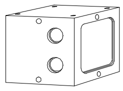
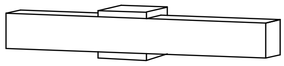
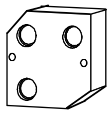
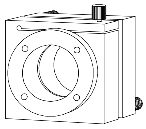
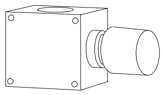
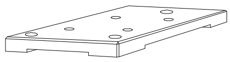
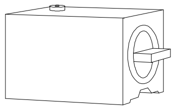
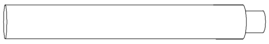
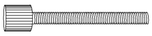
Straightness interferometer 128 269302-4012.824		Quantity:1
Measuring mirror 165 269302-4016.524		Quantity: 1
Beam offset prism 120 269302-4008.424		Quantity:1
Tiltable holter 524 269302-4010.925		Quantity: 1
Clamping device 507 269302-4010.325		Quantity: 2
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic base 506 260298-3000.128		Quantity: 2
Columns 140 / 90 or 200 260297-9900.128 **140** 260297-9900.228 **90** 260297-9900.328 **200**		Quantity: 2
Set of screws 269302-4005.624		Quantity: 1

Fig. 3: Optical and mechanical components to measurement roll angle

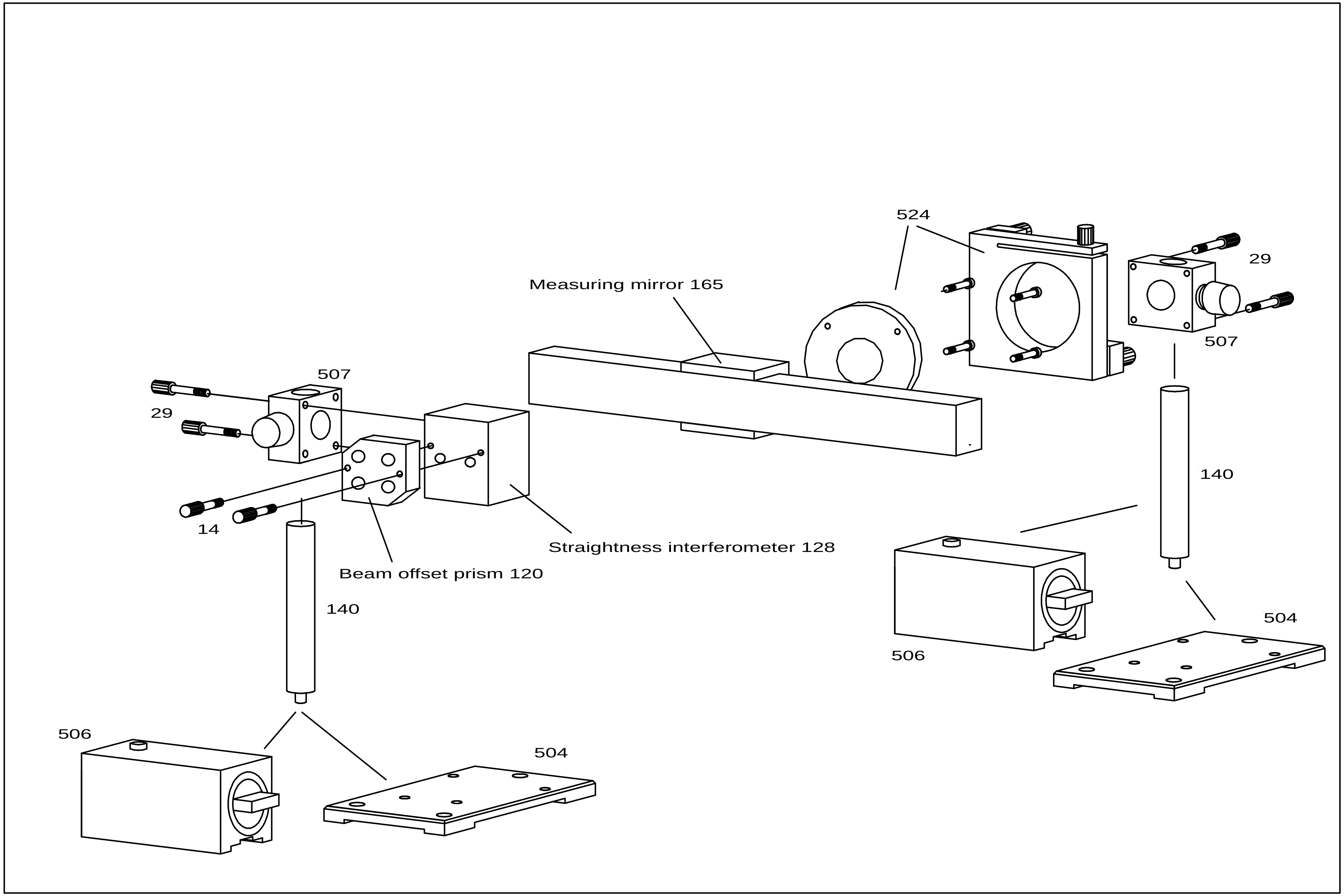


Fig. 4a: Roll angle measurment with straightness interferometer - horizontal configuration

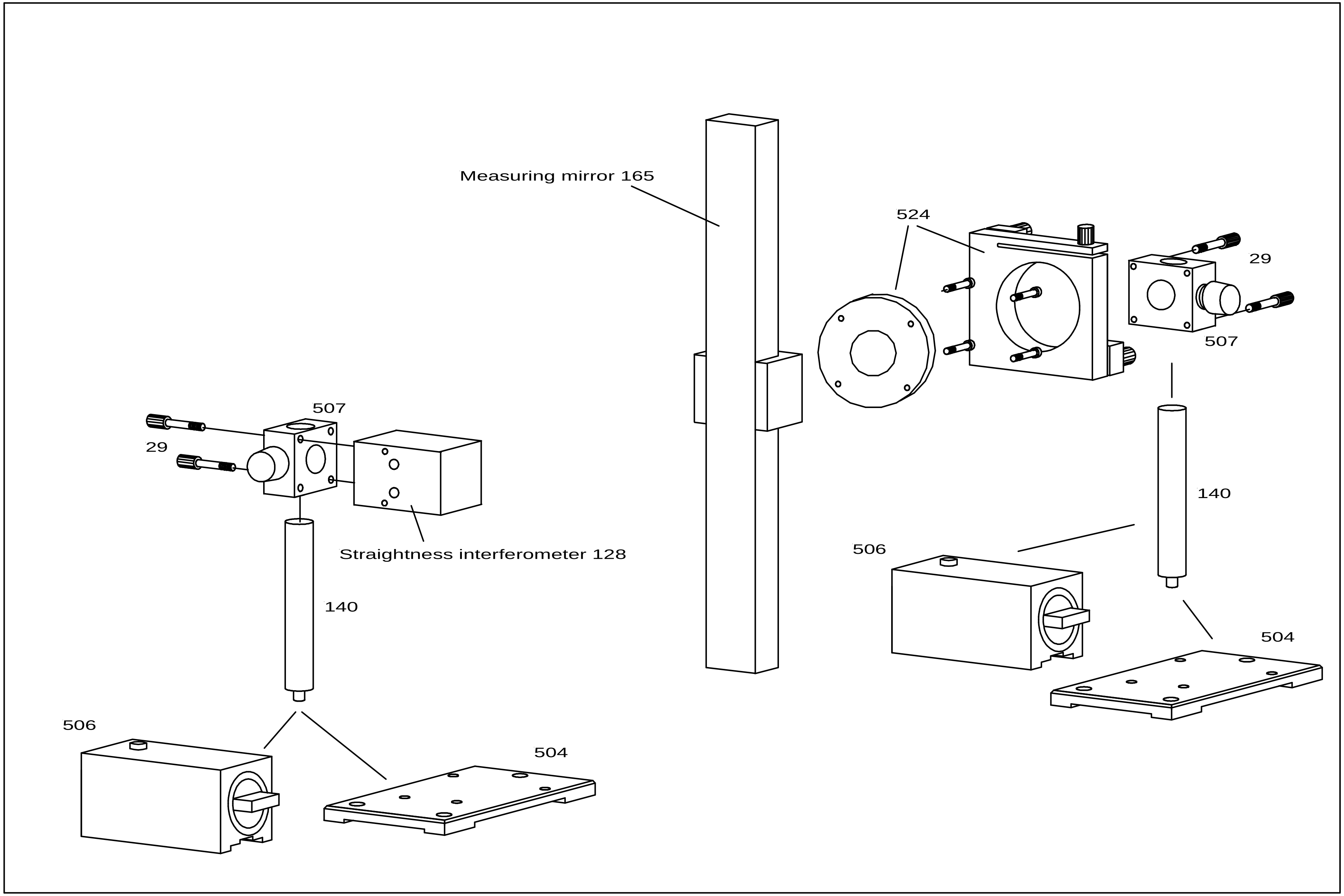


Fig. 4b: Roll angle measuring with straightness interferometer - vertical configuration

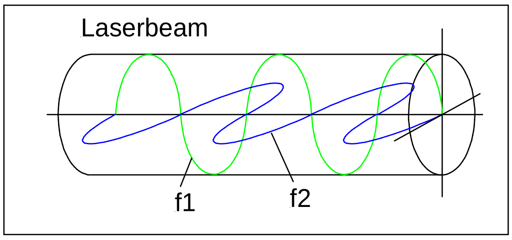
E Interferometer for Straightness Measurement

At the flatness measuring the deviations of straightness are measured indirectly by the progressive angle measuring. Unlike this deviations of straightness can be measured also directly by interferometer. Mirror areas which are worked very exactly in their planeness serve as straightness normal. Every unevenness of the mirror causes a systematic fault. The straightness deviations of guide ways at machine tools, coordinate measuring engines or other engines and devices particularly simply can be measured with the laser interferometer system.
The straightness interferometer serves the beam splitting. Double wedge and corner reflector constitute this straightness normal (Fig. 2).

Functional description

The light emerging from the laser unit enters a differential interferometer as the measuring beam. The vibration planes of the two frequencies emitted, f1 and f2, are perpendicular to each other (Fig. 3).

Fig. 1:
In the laser beam, the vibration plane of f1 is vertical, and that of f2 is horizontal.



Because of their different vibration planes (Fig. 1), the two frequencies are separated by a beam-splitting polarization coating in the differential interferometer.
Frequency f1 is deflected by 90°, as its vibration plane is parallel to the position and direction of the beam-splitting polarizer coat. It then passes the interferometer's half-wave plate, gets its vibration plane rotated by 90° and is deflected again by 90° by the interfe rometer.
Frequency f1 then passes a quarter-wave plate, after which it is again parallel to f2, which has passed the interferometer unaffected, thanks to its different direction of polarization. Passing the respective retardation plates (f1: $\lambda/2$ and $\lambda/4$ plates, f2:0 $\lambda/2$ plate) subjects both frequencies to circular polarization.
On striking the double wedge, both frequencies are refracted at a defined angle and then fall perpendicularly on the surfaces of the angular reflector, which reflects them back on themselves through the double wedge and to the interferometer. When they pass the retardation plates, both frequencies regain plane polarization, are reflected by the optical layers depending on their polarization direction and strike the respective corner reflector in the lower tier of the optical arrangement (tier II). Analogously to tier I (Fig. 4), both frequencies again travel along the optical path formed by interferometer, double wedge, angular reflector and back; when they pass the retardation plates again, their vibration planes are rotated. Now, frequency f1 vibrates horizontally and frequency f2 vertically, relative to the direction of beam incidence. Therefore, f1 is reflected by the polarizing beam-splitter coating at an angle of 90° relat ive to the laser head, whereas f2 passes the coating and enters the laser head.
With the double wedge being stationary, detector E1 registers the differential frequency of the laser (f1 - f2 = 640 MHz), which is equal to the electronic reference signal E2 detected in the laser head. If the double wedge is moved, the optical path lengths of the two frequencies passing it are changed, so that the respective measuring distance δz becomes either shorter or longer. The frequency changes (df1, df2) are proportional to the transverse displacement of the double wedge. They are detected by detector E1, since the beam has travelled the optical path twice.

$$\Delta f = (f1 + 4df1) - (f2 - 4df2) \qquad \text{oder} \qquad \Delta f = (f1 - 4df1) - (f2 + 4df2)$$

depending on the direction of mirror displacement.
In the high-frequency section of the laser interferometer system, the two detected signals (E1 and E2) are compared with each other. The result obtained is the frequency shift produced by the Doppler effect; this shift is a measure of the wanted transverse displacement of the double wedge.

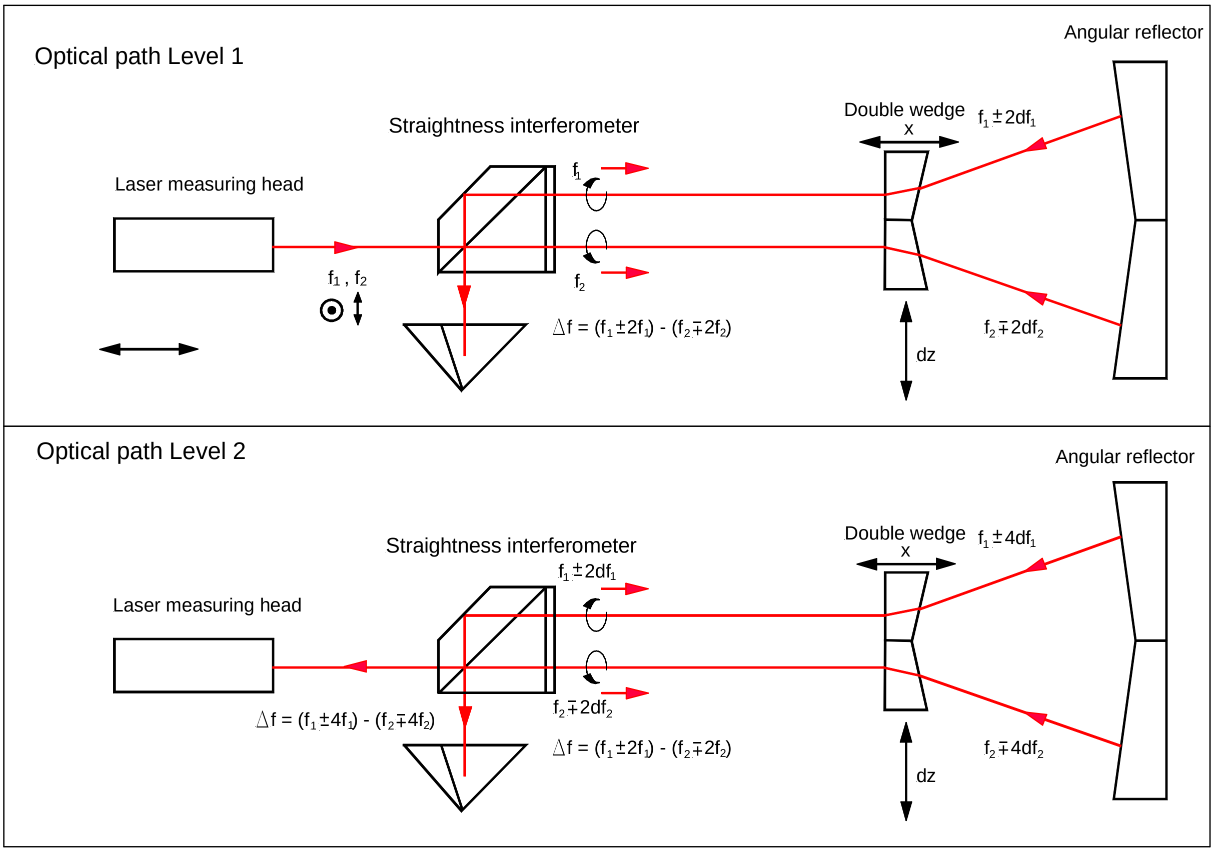


Fig. 2: Optical path in the different levels of the straightness interferometer

It must be distinguished

1. the detection of horizontal straightness errors
2. the detection of vertical straightness errors

At a vertical straightness measuring the Beam offset prism 120 must in addition be used so that the beam coming back from the interferometer can enter the laser measuring head (Fig. 4b).
In the Beam offset prism 120 taking place one beam redirection about diagonal and therewith one shifting to 90°.

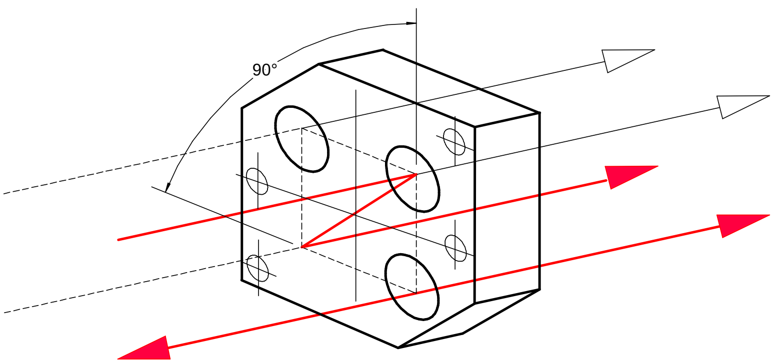


Fig. 3: Function of the Beam offset prism 120

There are 2 options for the straightness measuring at the ZLM 700:

1. straightnes measurement up to **2m length of axis** with a resolution of 29 nm
2. straightnes measurement up to **10m length of axis** with a resolution of 145 nm

<u>The optical moduls of the straightness measurement are:</u>

1 Straightness interferometer 128	***269302-4012.824***
1 Beam offset prism 120	***269302-4008.424***
1 Double wedge 108 *(2m)*	***269302-4010.824***
or 112 *(10m)*	***269302-4011.224***
1 Angular reflector 109 *(2m)*	***269302-4010.924***
or 113 *(10m)*	***269302-4011.324***

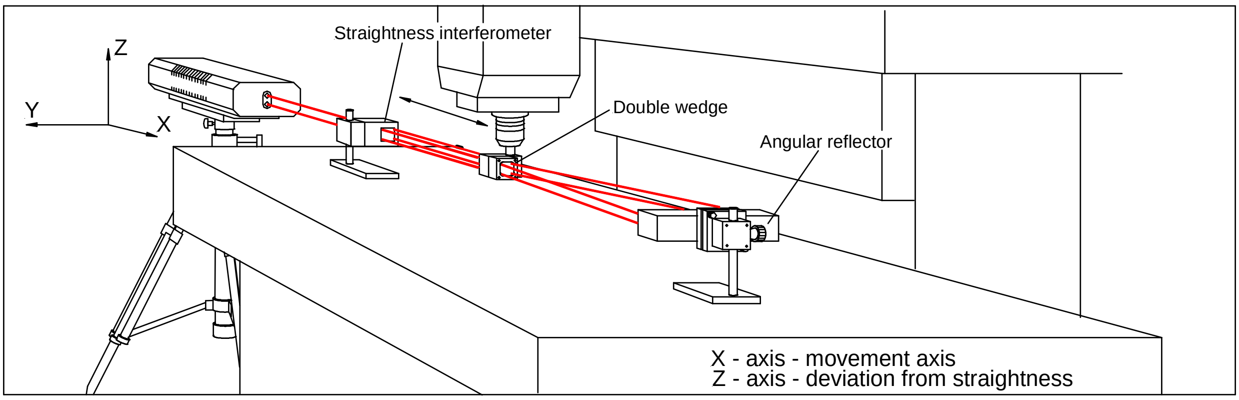


Fig. 4a: Measurement of straightness errors, horizontal configuration

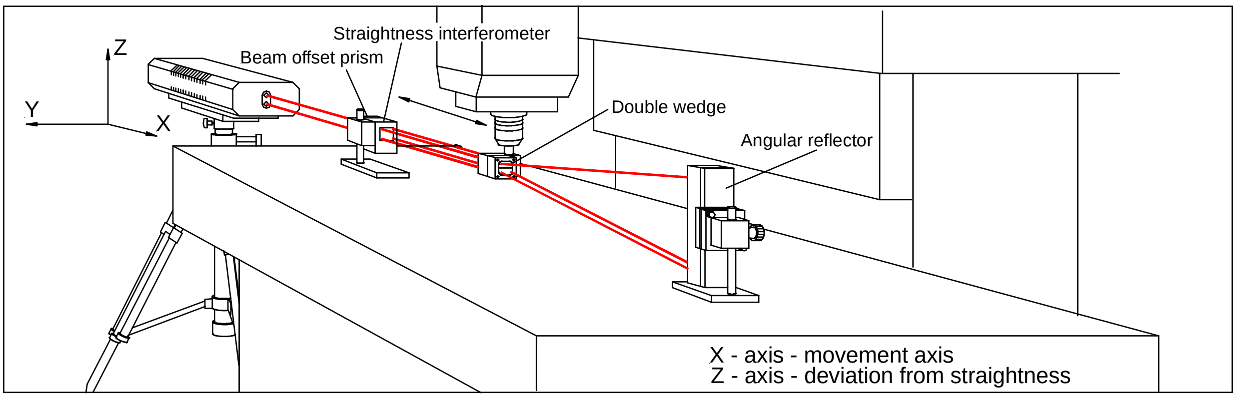


Fig. 4b: Measurement of straightness errors, vertical configuration

Assembly

The optical and mechanical modules and components of the equipment are shown by Fig. 5. Figs. 6 and 7 illustrate their assembly.

Straightness interferometer *(horizontal / vertical setup)*

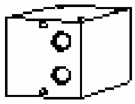
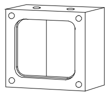
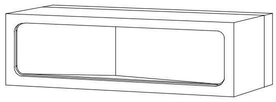
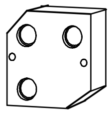
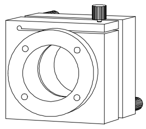
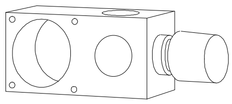
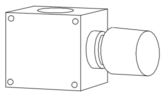
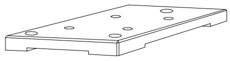
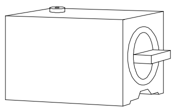
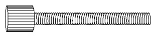
Differential interferometer 128 2693 02- 4012.824		Quantity: 1
Double wedge 2m / 10m 269302- 4010.824 **2m** 269302- 4011.224 **10m**		Quantity: 1
Angular reflector 2m / 10m 269302-4010.924 **2m** 269302-4011.324 **10m**		Quantity: 1
Beam offset prism 269302-4008.424		Quantity: 1
Tiltable fixture 524 269302-4010.925		Quantity: 1
Clamping fixture 508 269302-4010.125		Quantity: 2
Clamping fixture 507 269302-4010.325		Quantity: 1
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic base 506 260298-3000.128		Quantity: 2
Column pin 90 140 or 200 260297-9900.128		Quantity: 2
Set of screws 269302-4005.624		Quantity: 1

Fig. 5: Optical and mechanical modules and components of the Straightness Interferometer

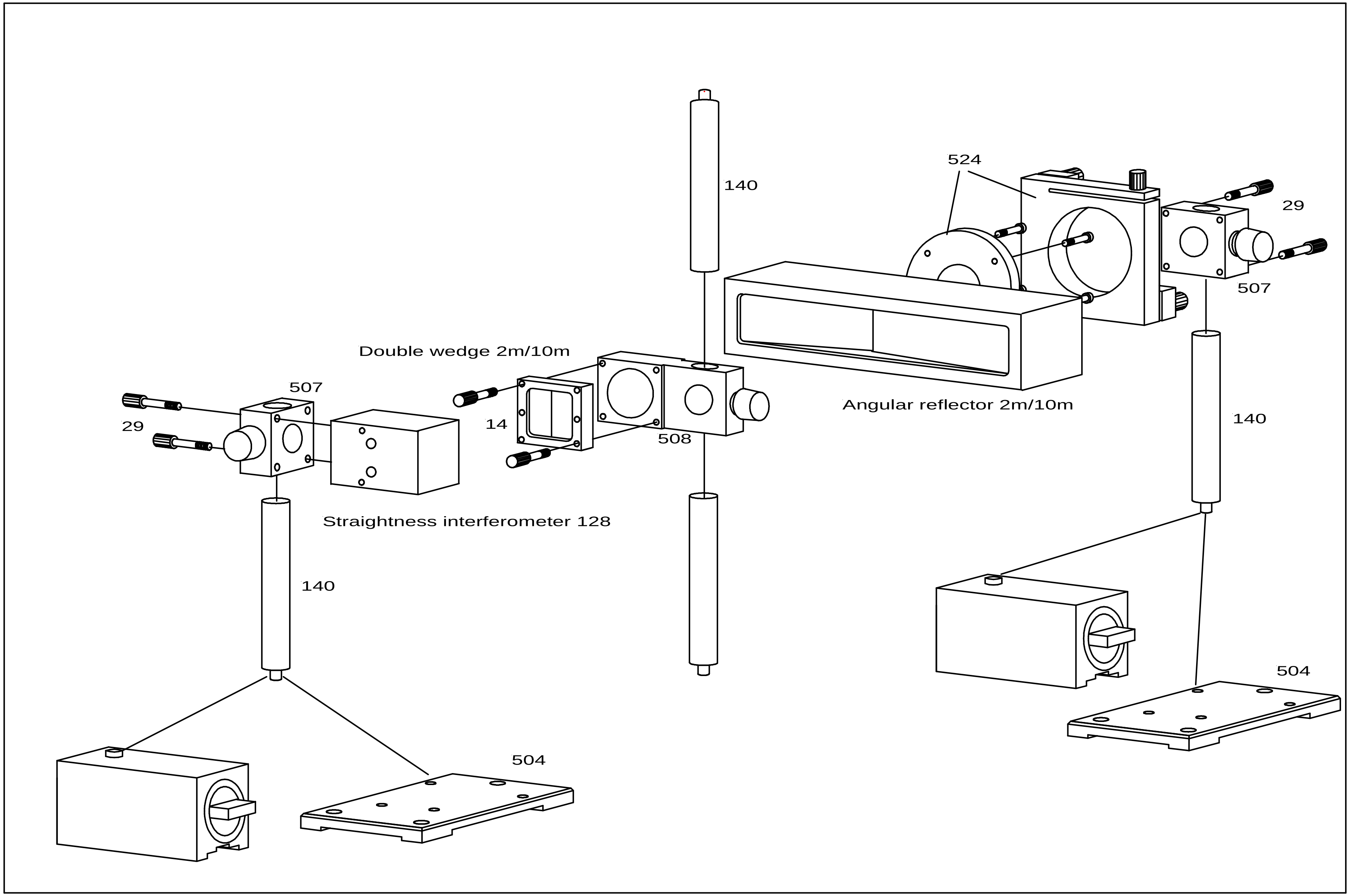


Fig. 6: Straightness interferometer, horizontal configuration (assembly drawing)

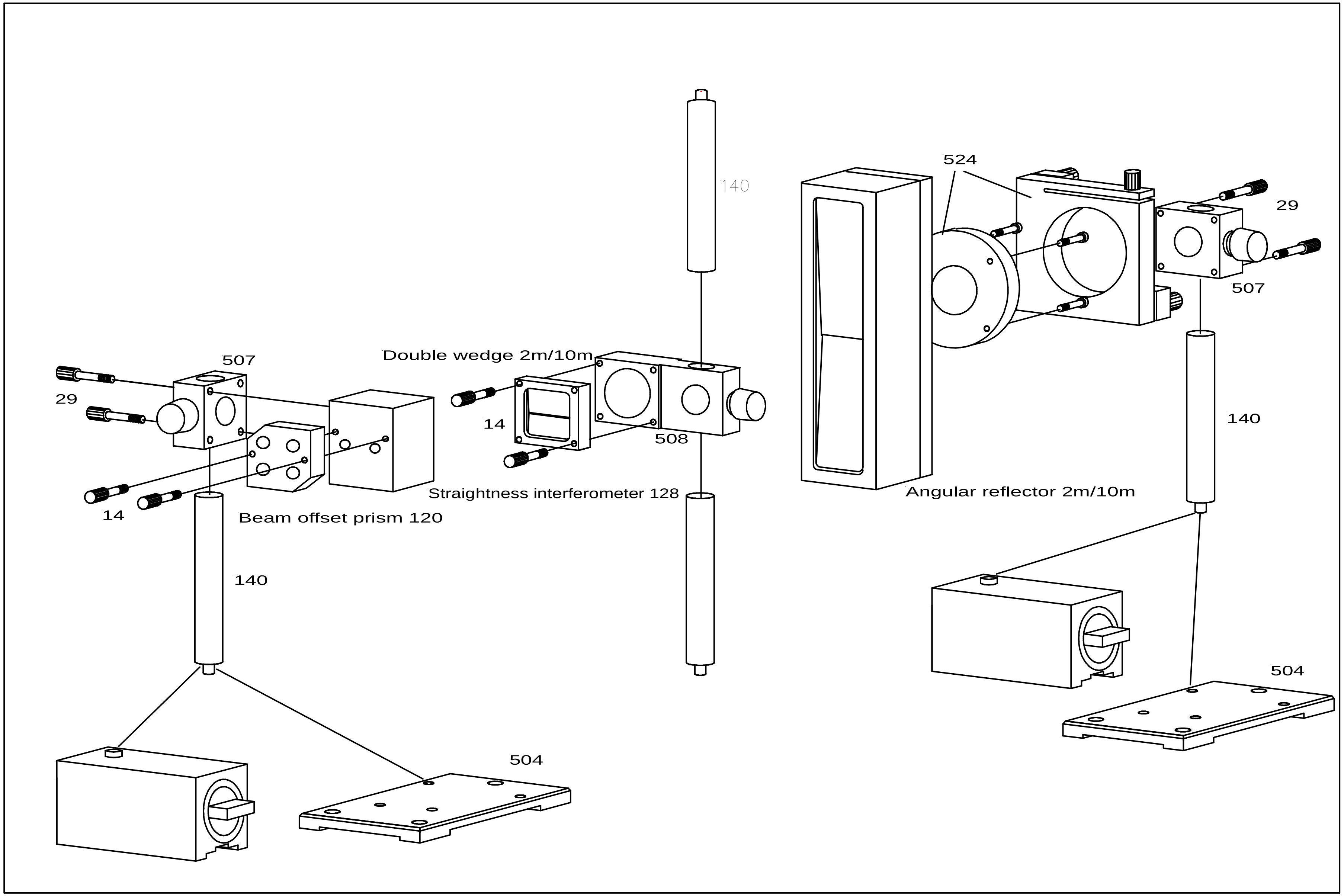


Fig. 7: Straightness Interferometer, vertical configuration (assembly drawing)

Measurement assembly

If all components **(laser head - straightness interferometer 128 - double wedge - angular reflector)** are assembled, the adjustment can start at the measurement object.
The set-up should be carried out for the two configurations (horizontal, vertical set-up) in the following steps:

1. Identify the axis of motion to be measured and find a location on the moving part of the object where the Double wedge can be fixed (1).
   example: fig. 8 Spindle chuck (pinole) - Double wedge

2. Find two stationary reference points in line with the axis of motion, at which the interferometer and the angular reflector can be rigidly fixed.
   example: fig. 8 Machine bed - Angular reflector
   Machine bed - Interferometer

> **IMPORTANT:**
> The optical modules must be so located that the point of location on the motion axis, the stationary reference point of fixing the interferometer and the beam exit port of the laser head can be aligned on a line in parallel with the motion axis.

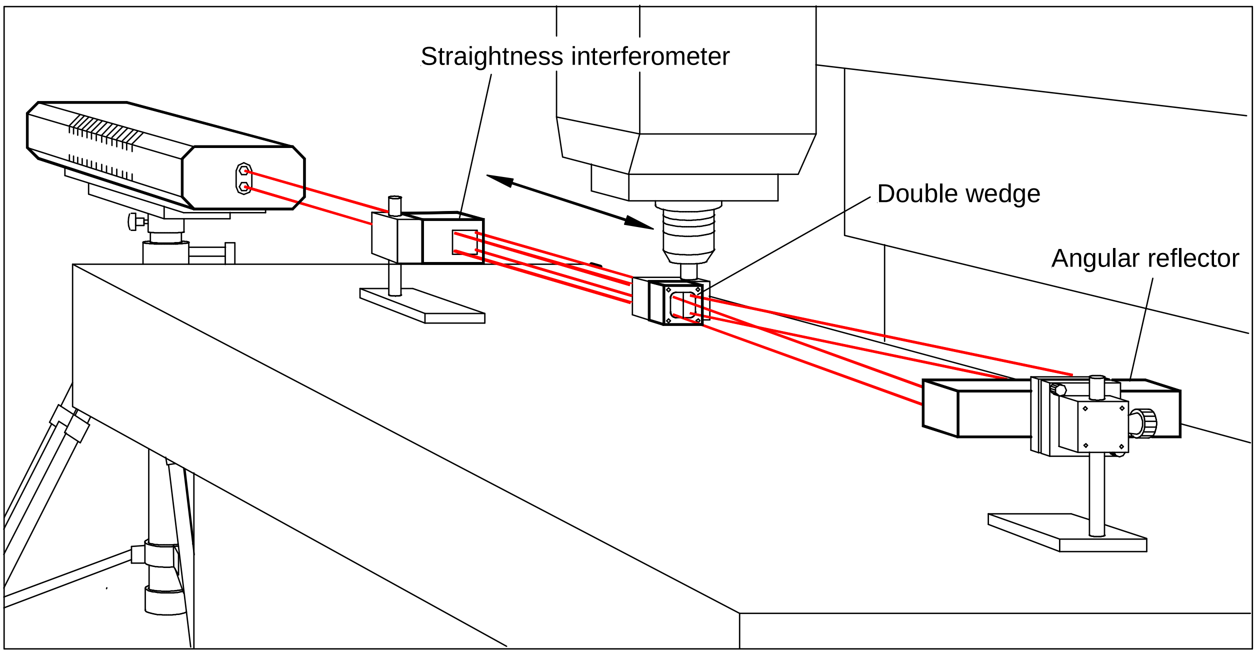


Fig. 8: Measurement setup at a machine tool

3. Fix the optical modules at the locating points found, wherever possible, in order to reduce measurement errors.

> **IMPORTANT:**
> Interferometer and corner reflector must have equal distances to the measuring line (h1 = h2) in order to avoid angular errors. fig. 9

4. Roughly align the laser beam with the optical axis of the installed optical modules.

Tips:

(1) Position the laser head as closely as possible to the interferometer (X_{tot}).
(2) Position the angular reflector at the most distant point possible from the interferometer (X_{max}) (Fig.9).
(3) Check whether the adjustable table is at the centre of its parallel displacement and tilting ranges. ⇨ This is important to ensure sufficient freedom of adjustment both ways during fine alignment of the beam path.

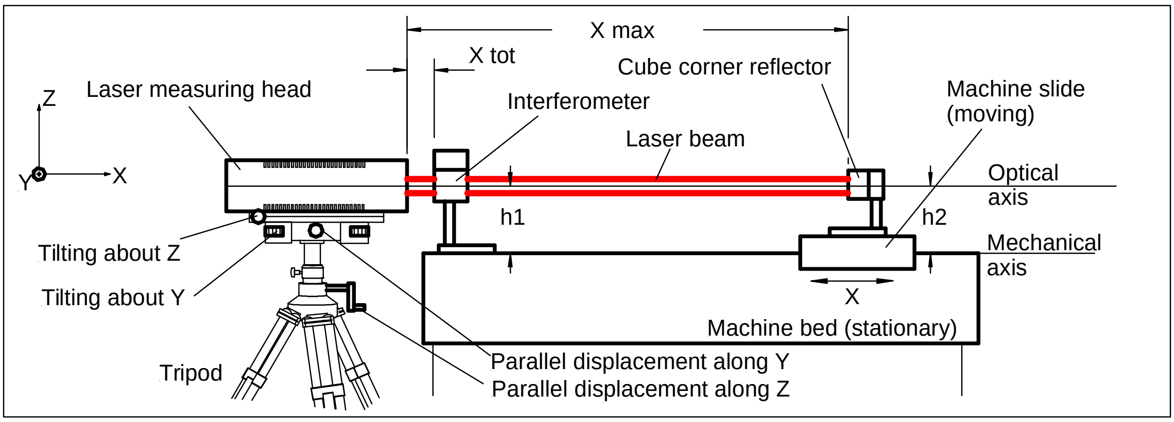


Fig. 9: Measuring setup, optical path

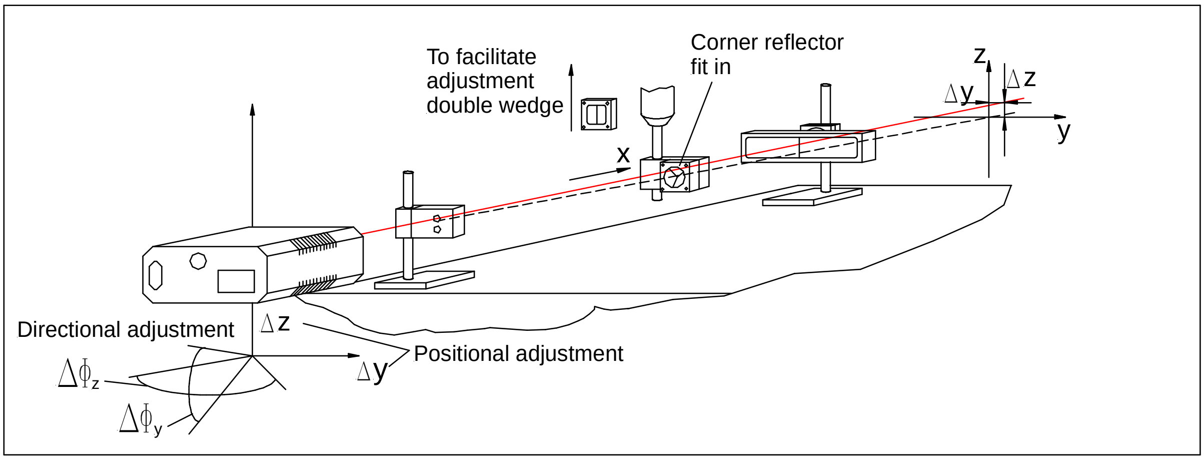
5. Fine alignment of the beam path

Tips:

To facilitate the alignment of the optical path in parallel with the measuring axis, remove the Double wedge from the beam path and fix a corner reflector in the beam path ⇨ That way, only one beam returns to the Straightness interferometer 128, which makes it easier to assess the state of alignment. ⇨ using the direct beam (see fig. 10), (covering the other beam)
***Advice:** As Cube corner reflector the Double corner reflector 160 can be used.*
This is exchanged directly with the double wedge. At use of the Cube corner reflector 102 has to make sure, that the center by 7.5 mm is transposed. The Adapter plate 542 serves as a compensation.

A fundamental distinction is made (Fig. 10) between

- positional alignment (Δy, Δz) — (parallel displacement along y and z)
- directional alignment (Δϕy, Δϕz) — (tilting about y and z)



FFig. 10: Beam alignment with cube corner reflector

The ZLM 700 is designed so that both adjustment facilities are provided on the adjustable table / tripod assembly. The merit of this arrangement is that you do not have to constantly alternate between two adjusting locations (laser head - measuring reflector).
For place and direction justification it is very important the position (place) of the Cube corner reflector to the Straightness interferometer (see fig.s 11, 12).

Positional alignment, Parallel displacement ⇨ at the Cube corner reflector position nearest to the laser

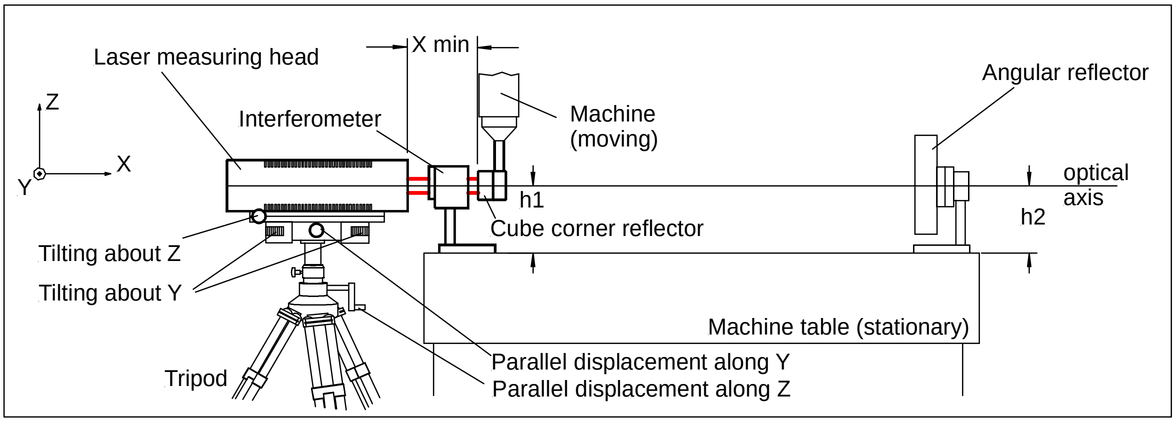


Fig. 11: Positional alignment of the beam path

Directional alignment, tilting ⇨ at the corner reflector position most distant from the laser head

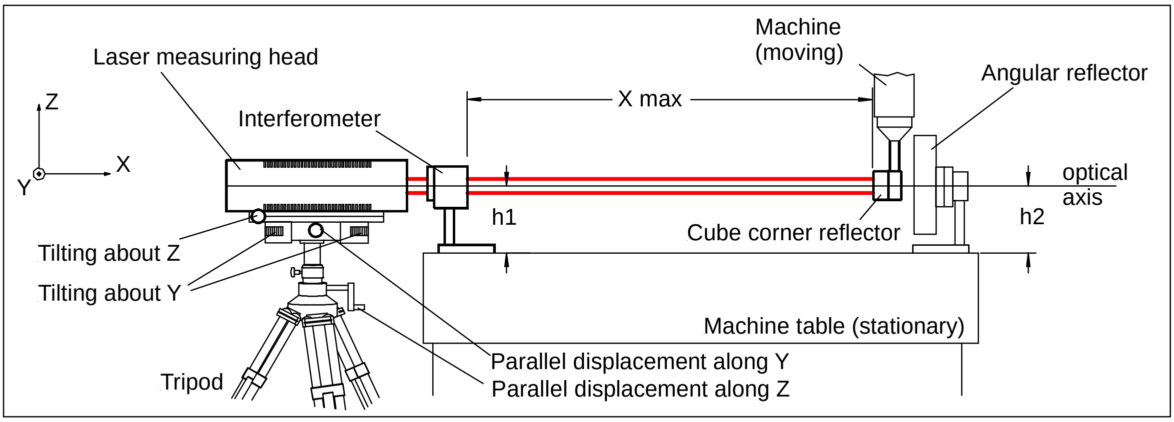
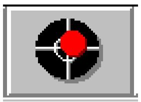


Fig. 12: Directional alignment of the beam path

Adjustment

From these basic principles, the following procedure of aligning the beam path results:

1) Select menu item  in the "Measurement" program routine.
In this menu item, the powers of the two beams reflected back into the laser head (reference and measuring beams) are represented by two spots on the monitor screen. The screen graph immediately shows the effect of alignment manipulations and thus allows the quality of alignment of the two beams to be checked and optimized.

2) Move cube corner reflector to the point most distant from the laser head and fix it there (Fig. 12).
Adjust the laser beam direction in y and z:

   $\Delta\Phi y$ - Turn the two lateral knurled screws of the adjustable table;
   $\Delta\Phi z$ - Turn the two knurled height adjustment screws of the adjustable table.

   Align until the reflected beam hits the beam entrance port of the laser head.
   For fine alignment, use the cross-lines shown on the screen.

3) Move cube corner reflector to the point closest to the laser and fix it there (Fig. 13).
Adjust the laser position in y and z:

   Δy - Turn the micrometer screw of the adjustable table to displace the laser in parallel.
   Δz - Turn the height adjustment handwheel of the tripod.

   Align until the reflected beam hits the beam entrance port of the laser head.
   For fine alignment, use the cross-liness shown on the screen.

   Repeat steps 2 and 3 alternatingly until no significant change in beam position (relative to the screen cross-lines) can be noticed.
   The permanent angular error between the optical and mechanical axes can be seen as the blue moving bar below the cross-lines presentation.

4) align the angular reflector by the following steps, Fig. 13
   - Exchange Cube corner reflector – Double wedge
   - horizontal and vertical justification of the Angular reflector on the two beams of the upper level

IMPORTANT:

Beams must hit the upper mirror face (upper tier) symmetrically to the centre line (roof edge) of the angular reflector.

- Align the Angular reflector by turning the aligning screws of its mounting fixtures so that the beams are reflected back into the incident direction. Both beams must pass again the Double wedge in the upper tier (observe the beams reflected back on to the Double wedge until they coincide with the beams coming from the interferometer). With correct alignment, both beams in the lower tier (Fig. 13) are reflected back on to the angular reflector.

- Both beams are in the lower level (with some lateral offset) of the Angular reflector. Through slightly turning the Angular mirror reflector is the beam path of the lower level vertically adjusted under the beam path of the upper level (Fig. 13).

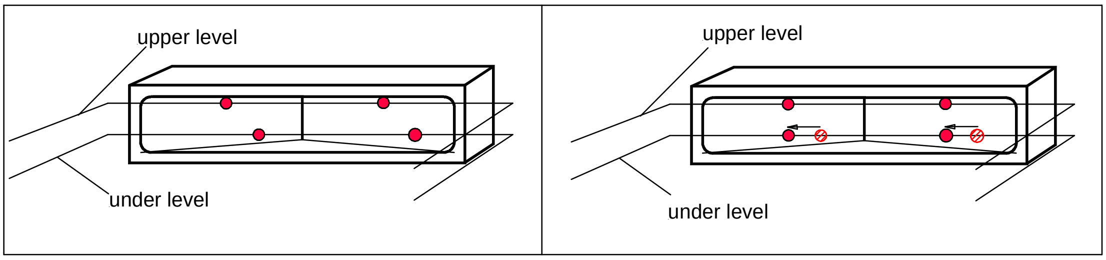
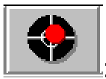


Fig. 13:

By correctly adjustment the laser beam is reflected into the under beam entry of the laser.

Finally, optimize the beam path by means of the screen graph :

IMPORTANT

Pay attention to the same local situation of the points of measuring and reference beam in the cross-lines.
(importantly for perfect interferenc signal)

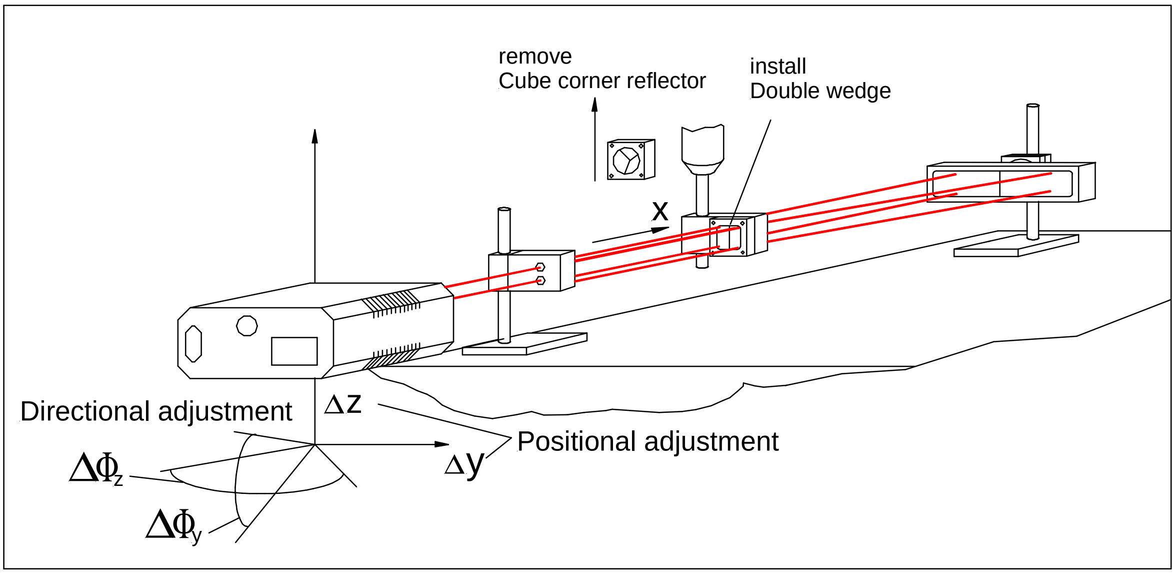


Fig. 14: Adjustment of the interferometer with the Double wedge

With the adjustment of Double wedge and Angular mirror reflector complete the alignment of the setup, which is now ready for measurement (see the Software Manual).

F Interferometer for Squareness measurement

The deviation of squareness of two machine axes can be measured as follows:

1. The straightness of a machine axis is measured.
2. The Angular reflector stops unchangedly as a reference after this measuring.
3. A 90°Pentagon prism (angular error ≦ 1“) becomes as a normal taken into the beam path of the second axis.
4. The straightness of the second axis is measured by the Pentagon prism to this in his position's unchanged Angular mirror.

The result are the straightness deviations of two axes in reference to the squareness standard (pentaprism).

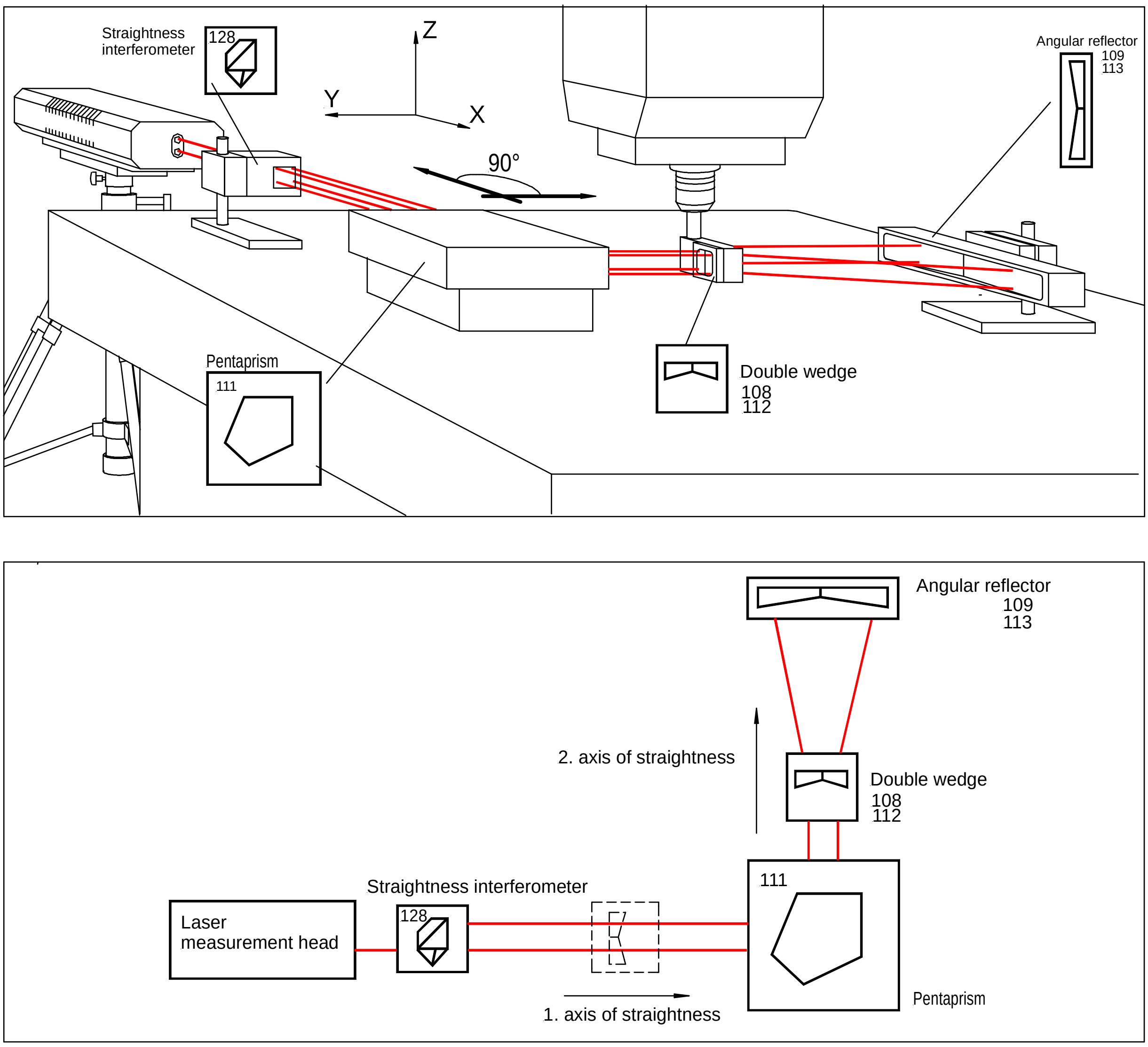


Fig. 1: Setup for squarness measurement (horizontal)

The squareness measuring can be looked (through adding further optical elements) as an expansion of the straightness measuring. The straightness measurings of the two axes must lie in the same level as their right-angled allocation.
Depending on position of the axes it will be distinguished in:

1. horizontal squareness measuring (Fig.1)
2. vertical squareness measuring (Fig.2).

The squareness measuring can be used for the two straightness options: **2m length** and
10m length

The optics modules of the squareness measuring are:

1 Straightness interferometer 128	***269302-4012.824***
1 Offset prism 120	***269302-4008.424***
1 Double wedge 108 2m	***269302-4010.824***
or **112 10m**	***269302-4011.224***
1 Angular reflector 109 2m	***269302-4010.924***
or **113 10m**	***269302-4011.324***
1 Pentaprism 111	***269302-4011.124***
1 Corner reflector 116	***269302-4011.624***
1 90° Beam bender 110	***269302-4011.024***

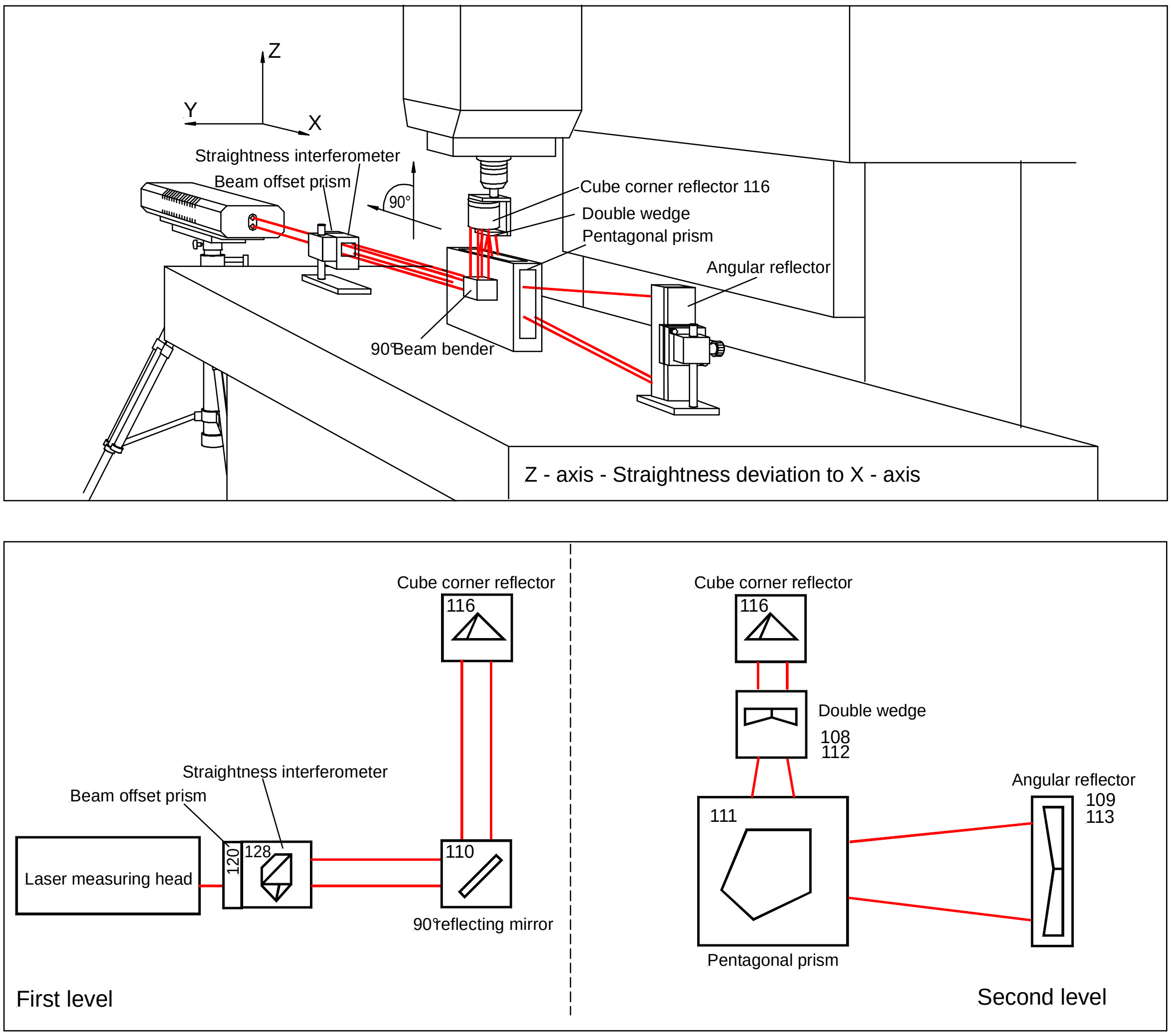


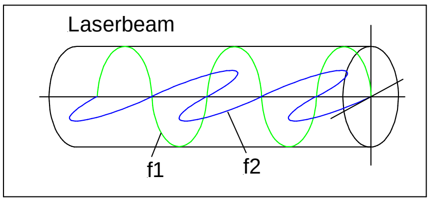
Fig. 2 : Setup for squarness measurement (vertical)

Functional description

A Pentagon prism is used as measuring normal. This embodies the 90° angle with a low measuring inaccuracy (≦ 1“). The measurement of the axes (in its 90° reference to each other) is made by straightness measurings according to the interferometrical principle (how it is described on the pages E1-E11). After measuring the first axis the Angular reflector remains at its place. The **Angular reflector** (the straightness normal) is the common reference of two measuring axes to each other.
For the squarreness measurement of the axes the beam path is enlarged.
To this the **90°beam bender** (screw together at the Pentaprism), **Corner reflector** with **Double wedge** (screwed together at the moved part of the measuring axis) and **Pentaprism** are inserted in the beam path. *(Fig. 3, Fig. 4a, Fig. 4b show the beam path in the levels).*

The light emerging from the laser unit enters a straightness interferometer as the measuring beam. The vibration planes of the two frequencies emitted, f1 and f2, are perpendicular to each other.

In the laser beam, the vibration plane of f1 is vertical, and that of f2 is horizontal.



Because of their different vibration planes, the two frequencies are separated by a beam-splitting polarization coating in the straightness interferometer. Frequency f1 is deflected by 90°, as its vibration plane is parallel to the position and direction of the beam-splitting polarizer coat. It then passes the interferometer's half-wave plate, gets its vibration plane rotated by 90° and is deflected again by 90° by the interferometer. Frequency f1 then passes a quarter-wave plate, after which it is again parallel to f2, which has passed the interferometer unaffected, thanks to its different direction of polarization. Passing the respective retardation plates (f1: $\lambda/2$ and $\lambda/4$ plates, f2:0 $\lambda/2$ plate) subjects both frequencies to circular polarization. They pass the 90° beam bender and are reflected by the corner reflector to the double wedge.
On striking the double wedge, both frequencies are refracted at a defined angle and then fall, via the pentaprism (straightness standard), perpendicularly on to surfaces of the angular reflector, which reflects them back on themselves to the interferometer via pentaprism, double wedge, corner reflector and 90° beam bender.
When they pass the retardation plates, both frequencies regain plane polarization, are reflected by the optical layers depending on their polarization direction and strike the respective corner reflector in the lower level of the optical arrangement (level II). Analogously to level I (Fig. 4), both frequencies again travel along the optical path formed by interferometer, 90° beam bender, corner reflector, double wedge, angular reflector and back; when they pass the retardation plates again, their vibration planes are rotated. Now, frequency f1 vibrates horizontally and frequency f2 vertically, relative to the direction of beam incidence. Thus, f2 is not reflected by the polarizing splitter and passes it to return to the laser head, whereas f1 is reflected by the polarizing splitter by 90° and also returns to the laser head.
With the double wedge being stationary, detector E1 registers the differential frequency of the laser (f1 - f2 = 640 MHz), which is equal to the electronic reference signal E2 detected in the laser head. If the double wedge is moved, the optical path lengths of the two frequencies passing it are changed, so that the respective measuring distance δz becomes either shorter or longer. The frequency changes (df1, df2) are proportional to the transverse displacement of the double wedge. They are detected by detector E1, since the beam has travelled the optical path twice.

$$\Delta f = (f1 + 4df1) - (f2 - 4df2) \quad \text{bzw.} \qquad \Delta f = (f1 - 4df1) - (f2 + 4df2)$$

depending on the direction of mirror displacement.

In the high-frequency section of the laser interferometer system, the two detected signals (E1 and E2) are compared with each other. The result obtained is the frequency shift produced by the Doppler effect; this shift is a measure of the wanted transverse displacement of the double wedge. With unchanged adjustment of the angular reflector - a basic requirement for squareness measurement - the squareness error between the two machine axes is obtained from the two straightness measurements by means of the pentaprism (the squareness standard).

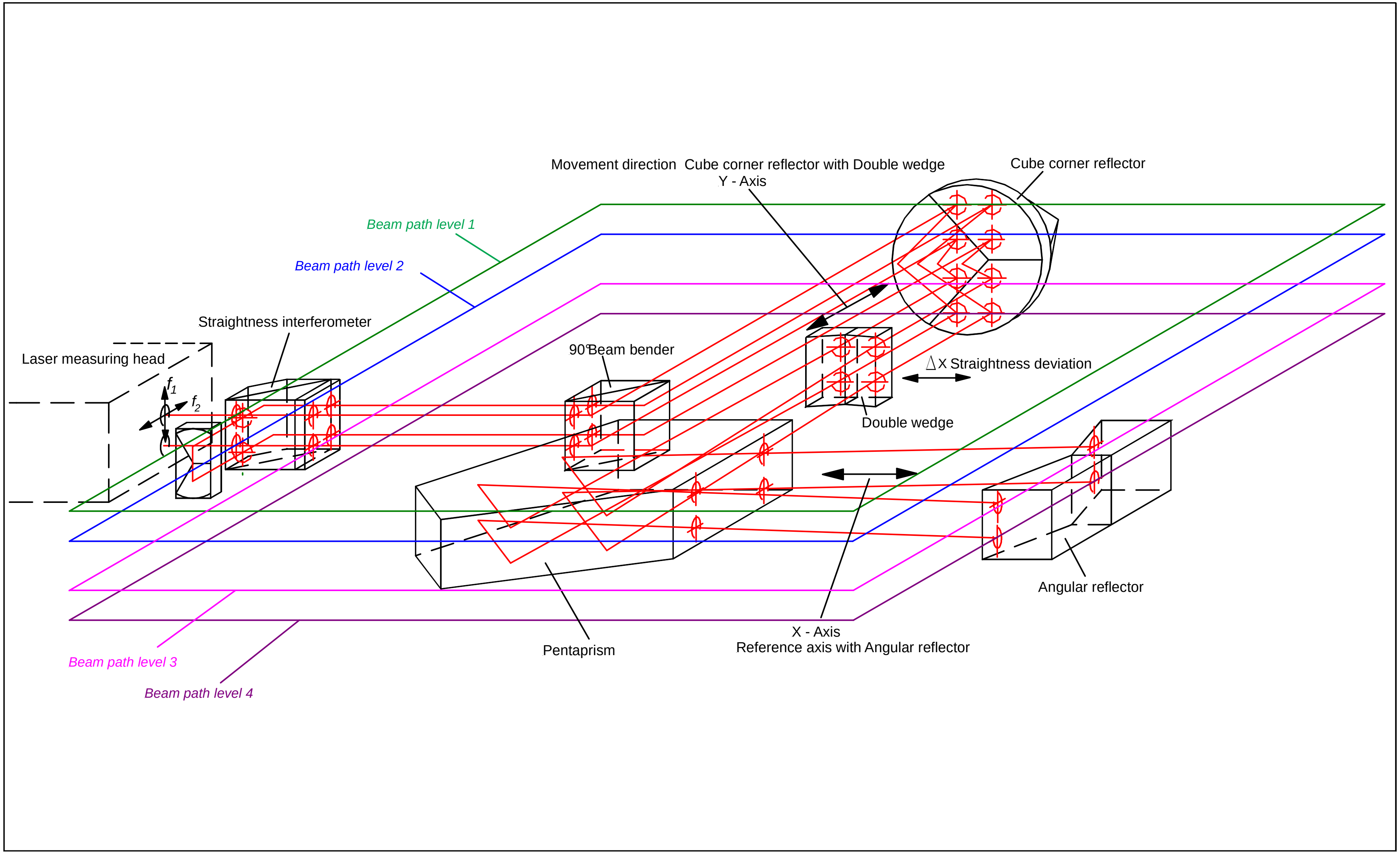


Fig. 3: Optical path - Squareness measurement

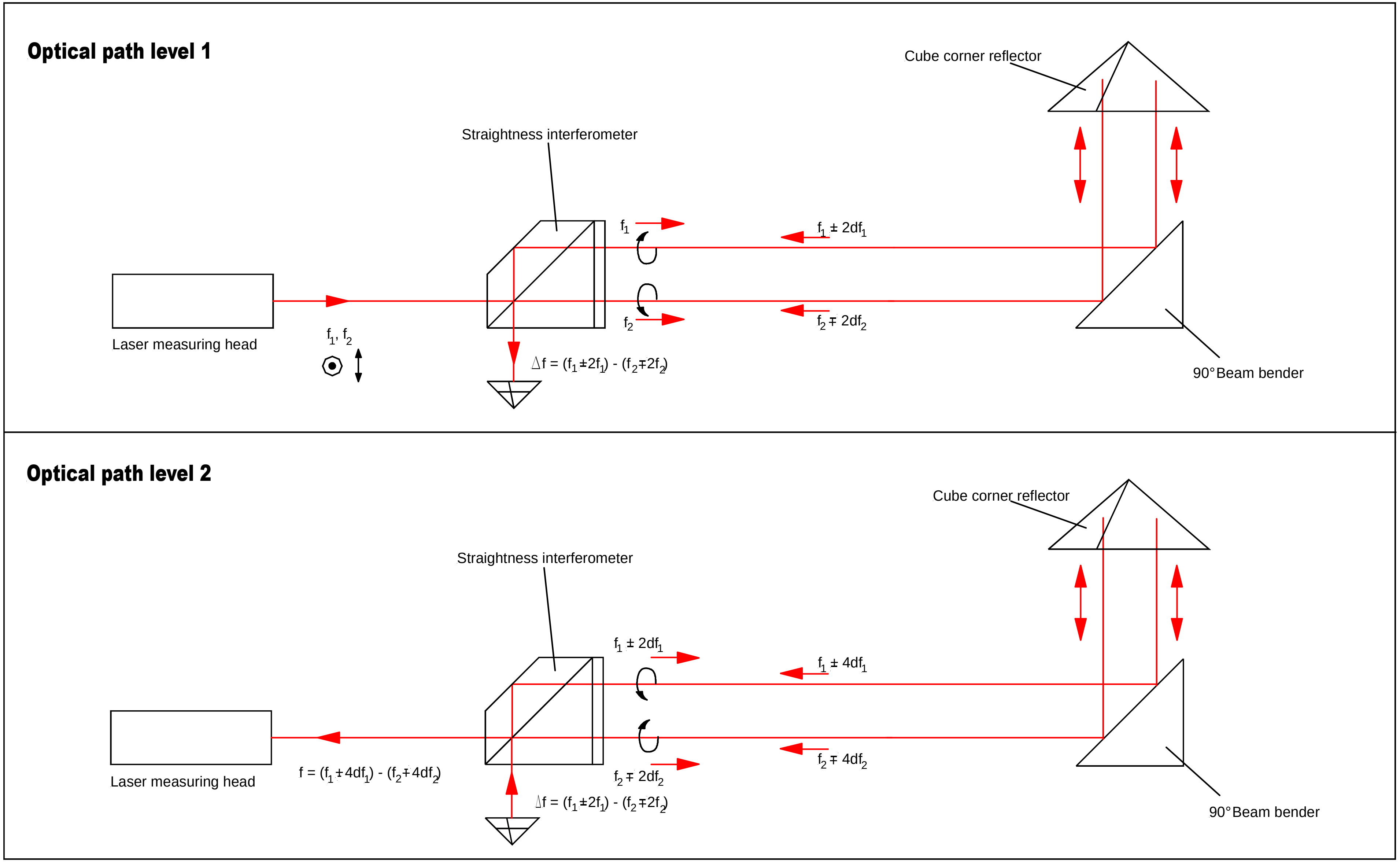


Fig. 4a: Operating principle straightness interferometer / squareness

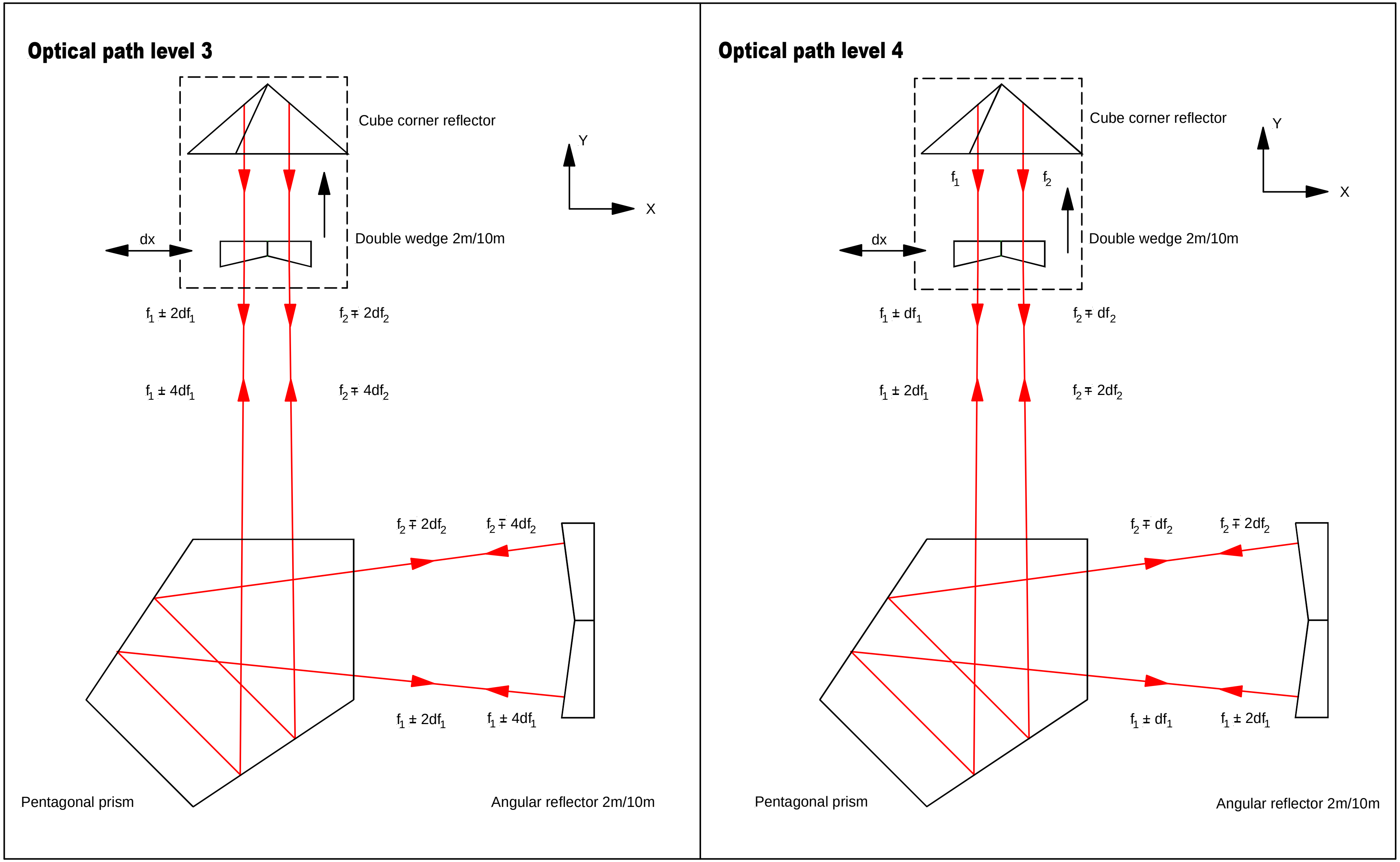


Fig. 4b: Operating principle straightness interferometer / squareness

Assembly

The optical and mechanical modules and components of the equipment are shown by Fig. 5. Figs. 6 and 7 illustrate their assembly.

Squareness interferometer

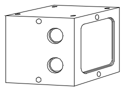
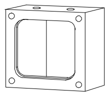
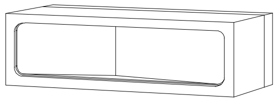
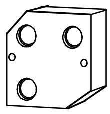
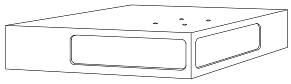
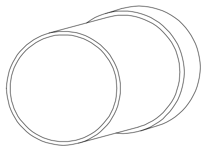
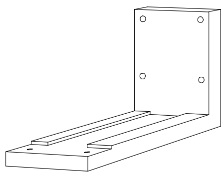
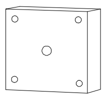
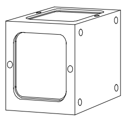
Straightness interferometer 128 269302-4012.824		Quantity: 1
Double wedge 108 (2m) / 112 (10m) 269302- 4010.824 269302- 4011.224		Quantity: 1
Angular reflector 109 (2m) / 113 (10m) 269302-4010.924 269302-4011.324		Quantity: 1
Beam offset prism 120 269302-4008.424		Quantity: 1
Pentaprism 111 269302-4011.124		Quantity: 1
Cube corner reflector 116 269302-4011.624		Quantity: 1
Angle bracket 521 269302-4010.425		Quantity: 1
Adapter plate 522 269302-4018.110		Quantity: 1
90° Beam bender 269302-4011.024		Quantity: 1

Fig. 5a : Optical and mechanical modules and components - Squareness (Part 1)

Squareness interferometer

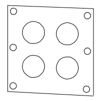
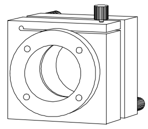
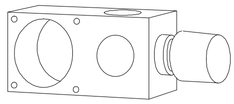
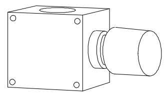
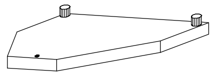
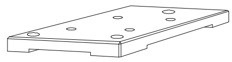
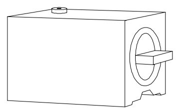
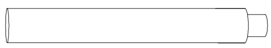
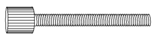
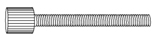
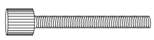
Blende 519 269302-4014.310		Quantity: 2
Tiltable fixture 524 269302-4010.925		Quantity: 1
Clamping fixture 508 269302-4010.125		Quantity: 2
Clamping fixture 507 269302-4010.325		Quantity: 1
Adjusting plate 548 269302-4012.425		Quantity: 1
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic base 506 260298-3000.128		Quantity: 2
Column 200 / 140 oder 90 260297-9900.128		Quantity: 2
Set of screws 269302-4005.624		Quantity: 1
Knurled screw 29 269302-4011.225		Quantity: 4
Knurled screw 45 269302-4011.425		Quantity: 2

Fig. 5b: Optical and mechanical modules and components - Squareness (Part 2)

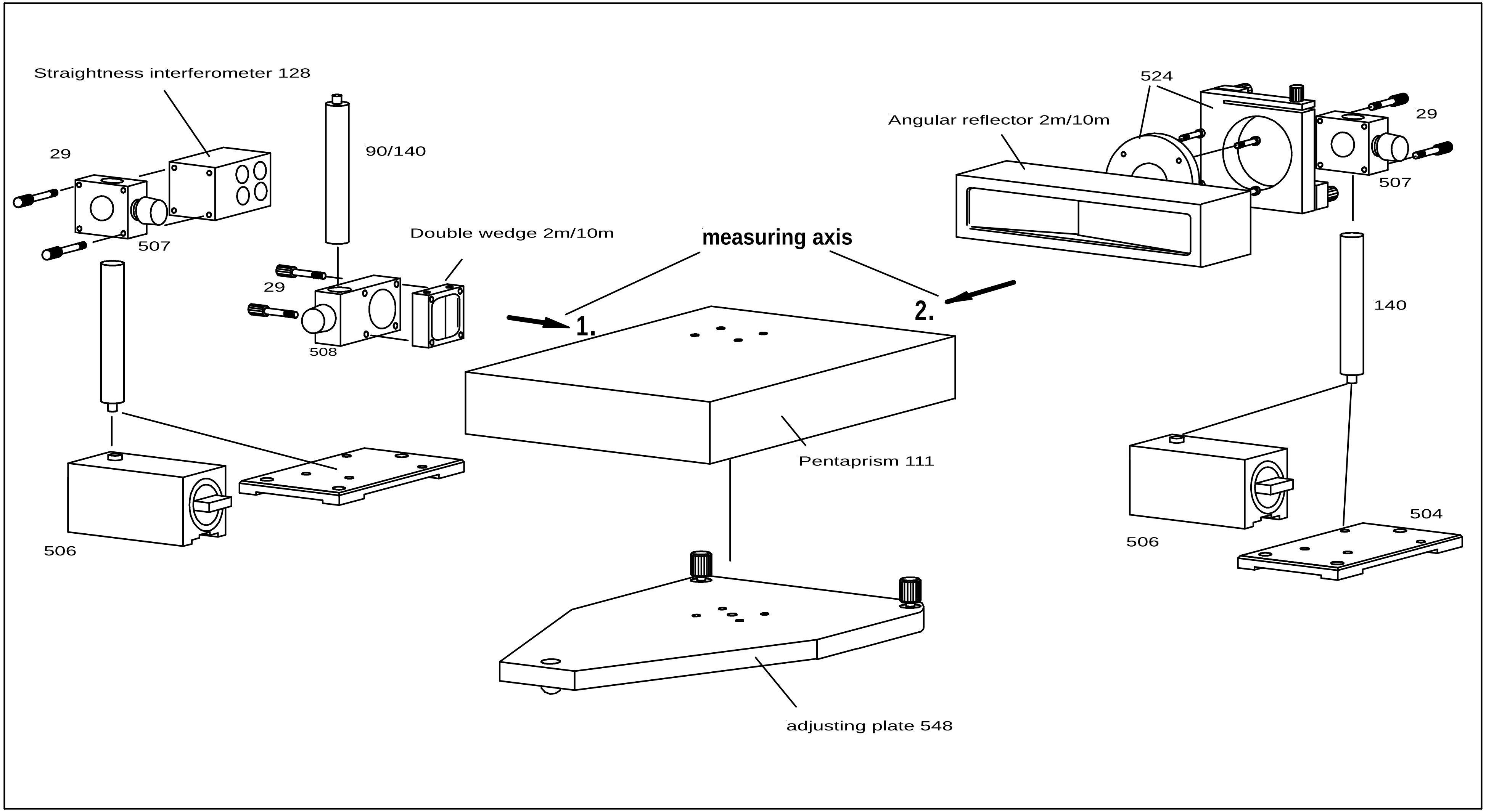


Fig.6: Squareness Interferometer, horizontal configuration (assembly drawing)

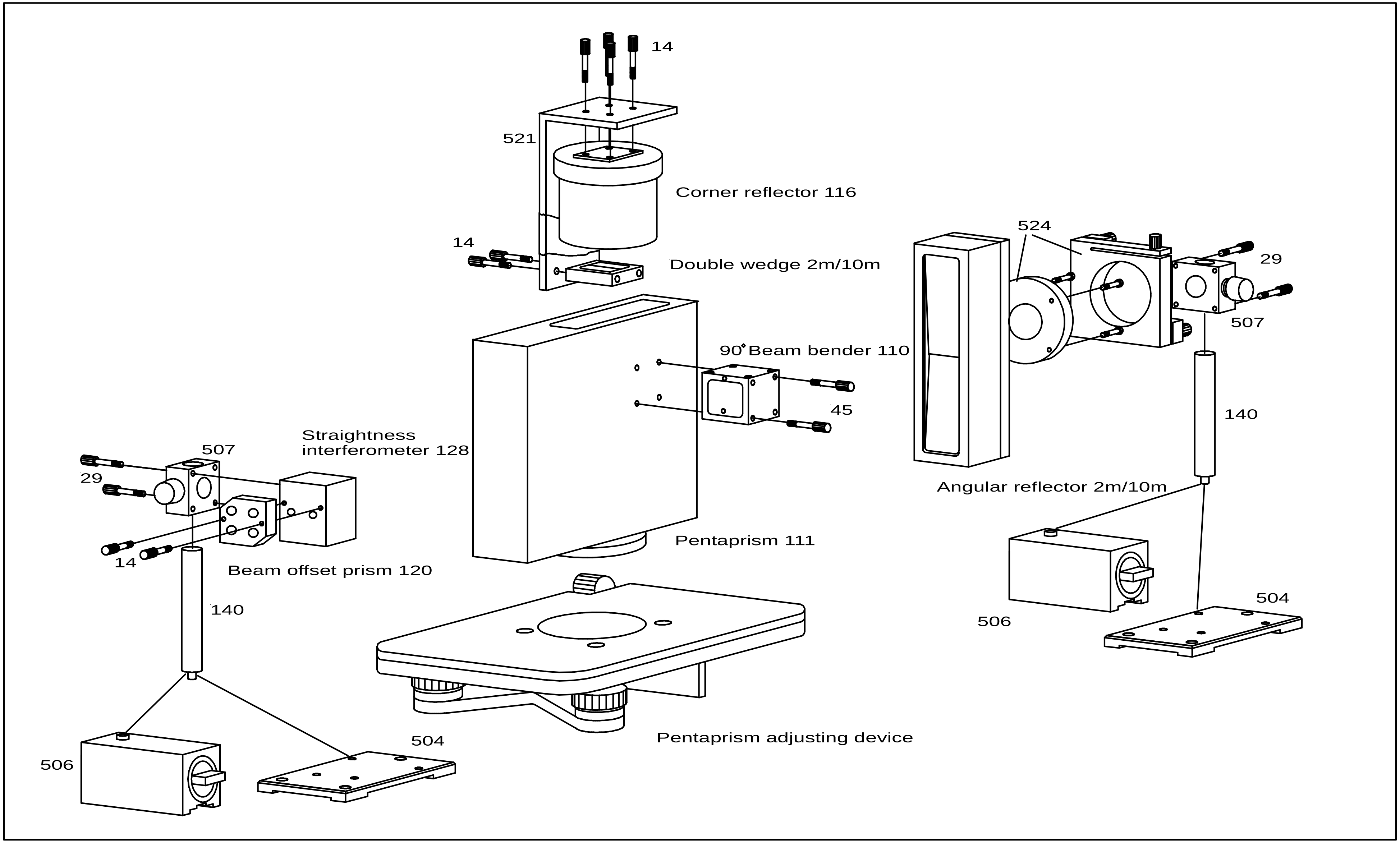


Fig. 7: Squareness Interferometer, vertical configuration (assembly drawing)

Adjustment

If all components are assembled, the justification can start. The installation procedure (for horizontal and vertical setup) should follow the sequence of steps described below:

1) Adjustment for straightness measuring of the base axis
corresponds to the description "Adjustment" in the chapter "Straightness interferometer" (page E7 to E11)

2) Adjustment of the square axis:

- The Angular reflector remains unchanged in its position.
- Find out a place suitable for the fastening of the Pentagon prism
- Fastening of the Corner reflector and the double wedge at the moveable part of the measurement object.
  example: Fig.1, Fig.2 Spindle chuck (pinole)
- lateral shifting of the laser measuring head and straightness interferometer by 40 mm.
- Position adjustment and directional alignment of the laser beam about straightness interferometer, 90°Beam bender, Cube corner reflec tor, Double wedge on the Angular reflector.

IMPORTANT

During this adjustment all construction elements can be changed in their position ***(-except the Angular reflector!!!)****.*

Tip

Because of the multiple convolution of the beam path this adjusting step takes time. Therefore careful preparations for the geometry of the setup are necessary before the adjustment starts.
It is expediently to use two four-beam stops 519. The first one should be fastened at the 90°Beam bender and the second one should be fastene d at the Double wedge. The Cube corner reflector must be assembled so that the laser beam hits on the areas (not on the edges, see Fig. 8).

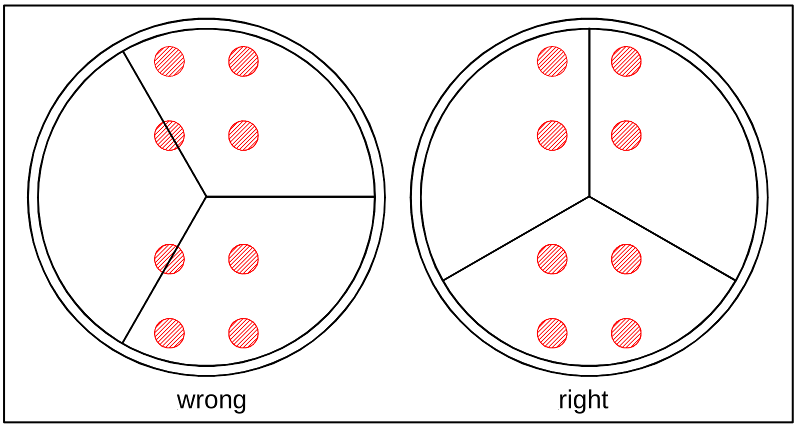
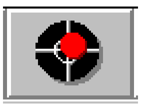


Fig. 8: The beam position at the Cube corner reflector.

3) Covering of measuring beam and reference beam



The adjustment is to carried out according to the chapter "Straightness interferometer" pages E10 and E11.

G Flatness Measurement

With the flatness interferometer the deviations from the flatness of surfaces (f.i. machine foundations, guide ways of machines) can be measured. The procedure is based on the progressive angle measuring. The flatness interferometer consists of the following components, Fig. 1:

1	**Angle interferometer 114**	***269302-4015.324***
1	**Double corner reflector 115**	***269302-4015.424***
2	**Base plate with turn mirror 118**	***269302-4015.524***
1	**Base distance plate 50**	***269302-4011.825***
1	**Base distance plate 100**	***269302-4011.725***
1	**Base distance plate 150**	***269302-4011.625***

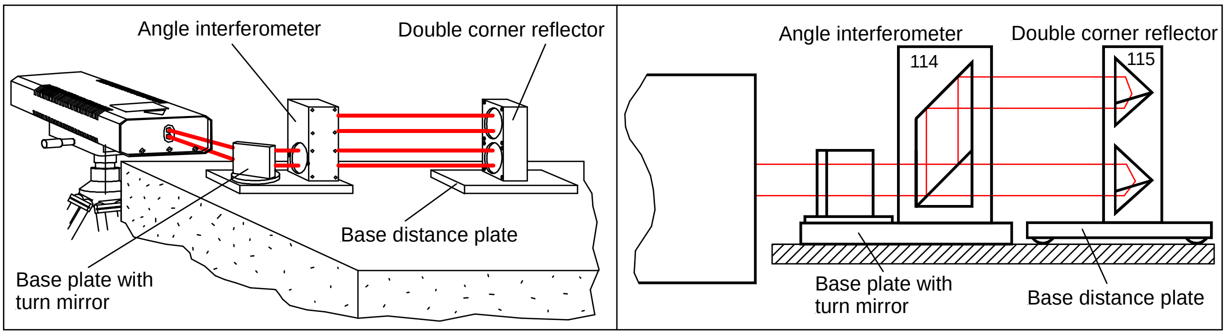


Fig. 1: Flatness interferometer (optical arrangement)

Functional description

Flatness interferometer

The flatness interferometer base functional princip of angle interferometer.
The two light modes emerging from the laser head are seperated by a polarizing beam splitter in the Angle interferometer. The mode deflected by 90° is bent by a 90° Beam bender so as to be parallel to the mode that passed the beam splitter unbent.
Because of the polarizing beam splitter, the measuring reflector only receives light of frequency f1, while the reference reflector only receives light of frequency f2.
With the corner reflector unit at rest, E1 detects the laser´s differential frequency (f1-f2=640MHz), which is equal to the electronic reference signal (E2) detected in the laser head.
If the Double corner reflector changes its angular position by $\Delta\varphi$ during linear movement, both partial beams are Doppler-Shifted by $\pm$df1 and $\pm$df2, respectively. Accordingly, detector E1 registers a measuring frequency of Δf_{Meas}=(f1$\pm$df1) - (f2$\pm$df2), depending on which way the measuring reflector is moved.
The two signals detected (E1 and E2) are compared with each other in the high-frequency section of laser interferometer system. The result optained is the frequency shift Δf_{Meas} due to the Doppler effect; this shift is a measure of the displacement Δx of the Double corner reflector (Fig. 2).

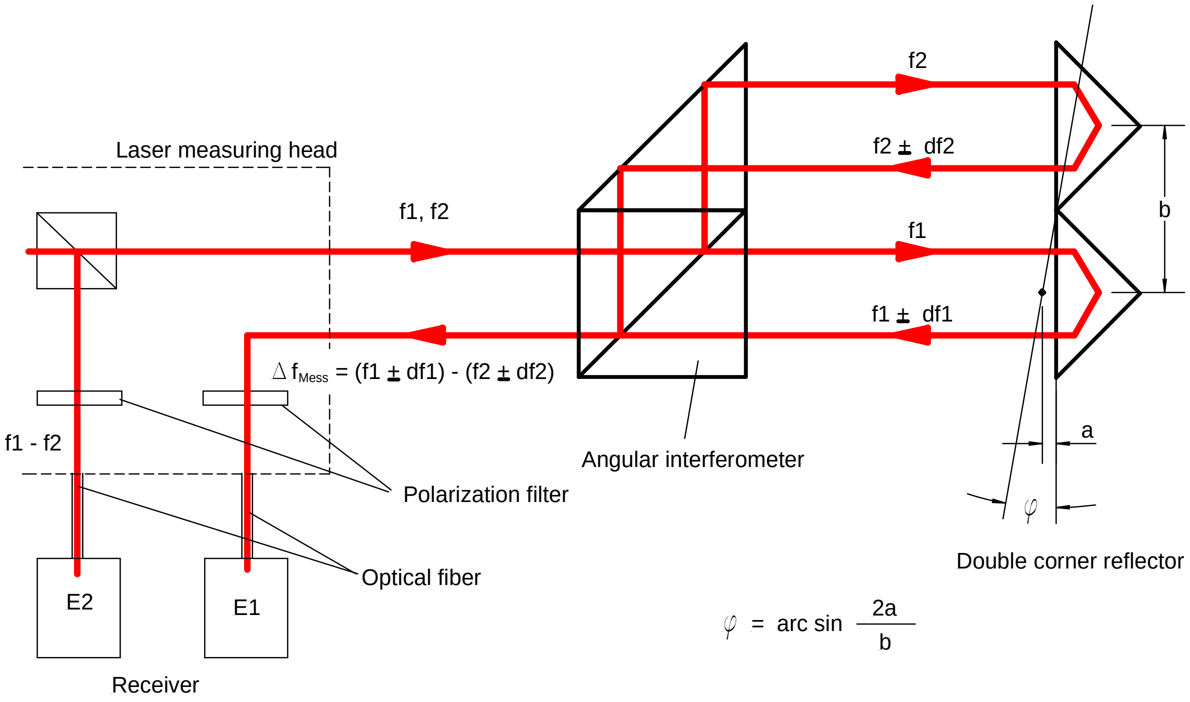


Fig. 2: Angle interferometer

Flatness measurement

The height profile (the profile of deviations from flatness) is the result of a number of individual straightness measurements made along a grid of lines (Fig. 3) having a fixed location relative to the surface under test. Two methods known as the Cross Jack and the Union Jack method are usual. (Fig. 4). The function and handling of these methods are explained in detail in the software manual and can be selected freely by clicking on the respective button on the graphic user environment.

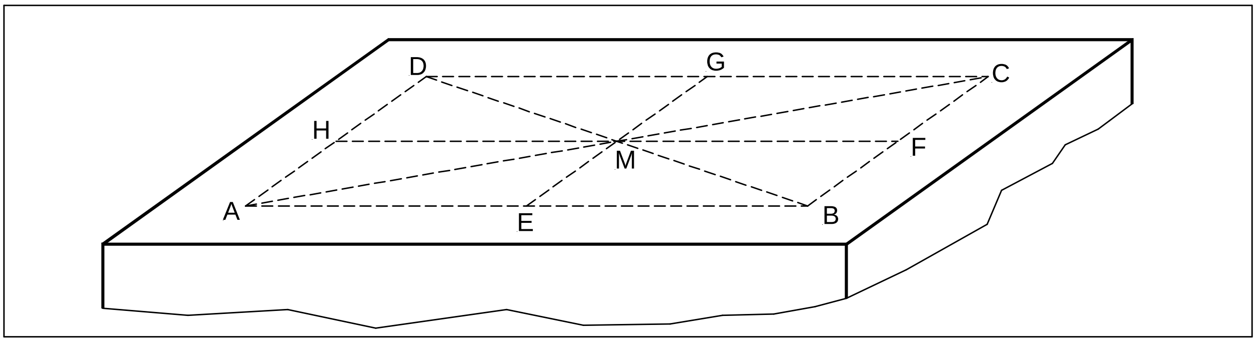


Fig. 3: Measuring grid „Union Jack“

The pre-certain lines have to be divided up into intervals depending on the number of scheduled measuring points. These intervals correspond the support points to base distance plates.
Three sizes are possibly: **150 mm, 100 mm und 50 mm**

The double reflector is assembled on the base distance plate. This is moved from the first measuring point along a grating line with the distance "s" to the next one, then to the next one and so on.
The laser beam may be interrupted **in no case** (because through it the measure connection to the previous measuring point is lost!).

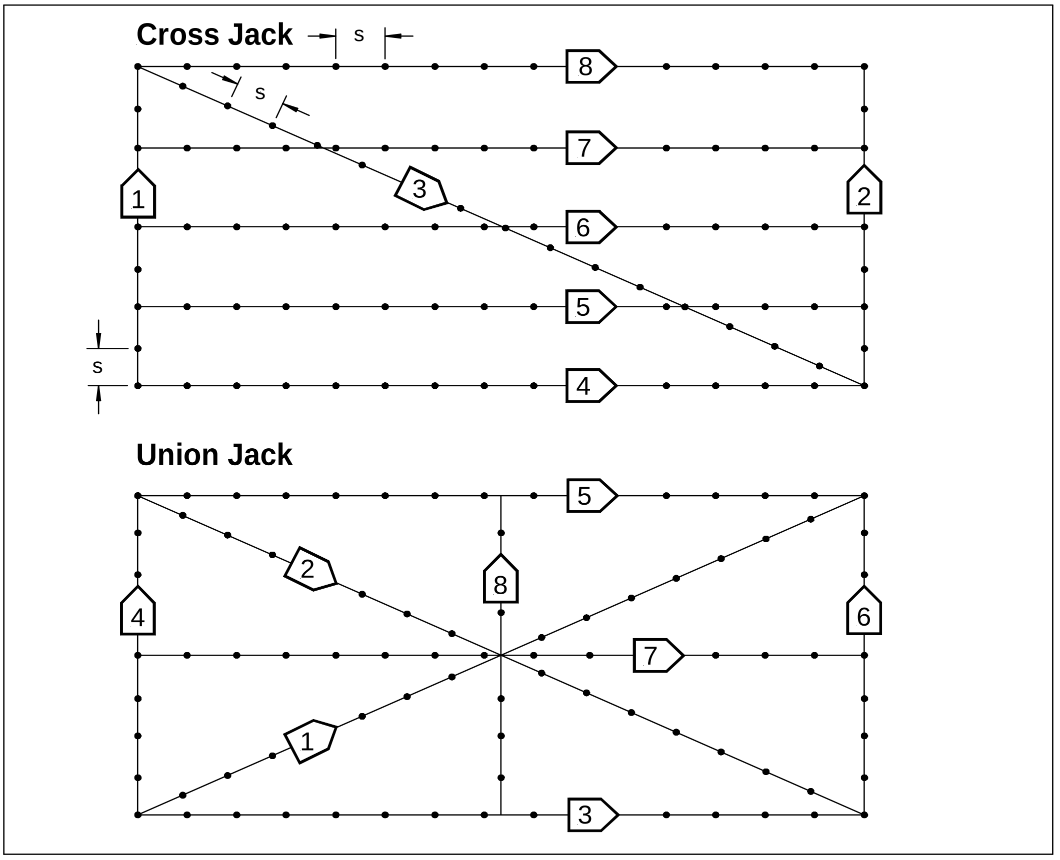


Fig. 4: Plan of the measuring grids

The height profile of the individual grating lines (1-8) arises from the differences of the height between the measuring points, the angle deviation $\Delta\varphi$ and the base distance "s" between the measuring points.

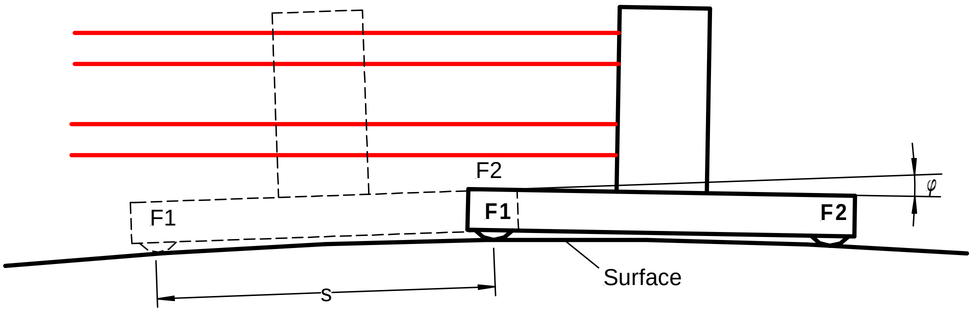


Fig. 5: Displacement of the double corner reflector with a base distance plate

The individual deviation is:

$$\delta z = s \cdot \tan \phi$$

By repeated displacement of the base distance plate carrying the Double corner reflector (base point 1 on the location of base point 2), the straightness deviations can be related to the various base point intervals (Fig. 6).

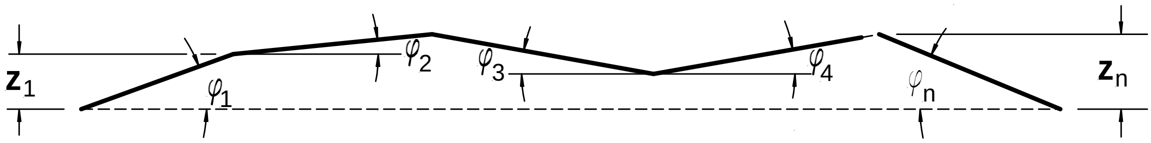


Fig. 6: Determination of the height (straightness) profile of a line

The height profiles of the individual lines are put together to the height profile of the complete plane. To this the individual heights are equated in a common measuring point (Fig. 7: Example of a common measuring point M at a distance δa) and corrected to a reference line.

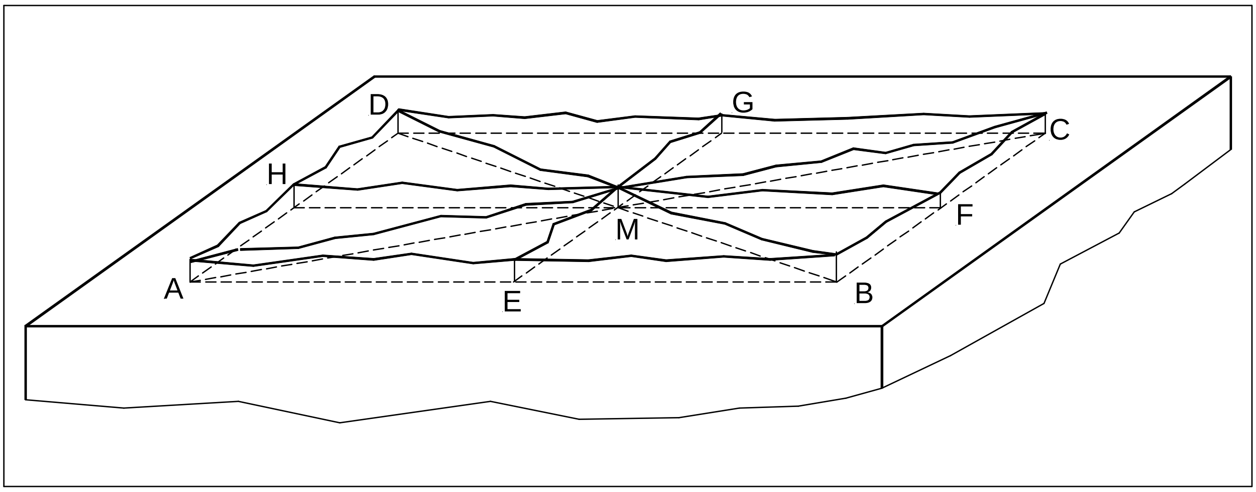


Fig. 7: Flatness of the total plane

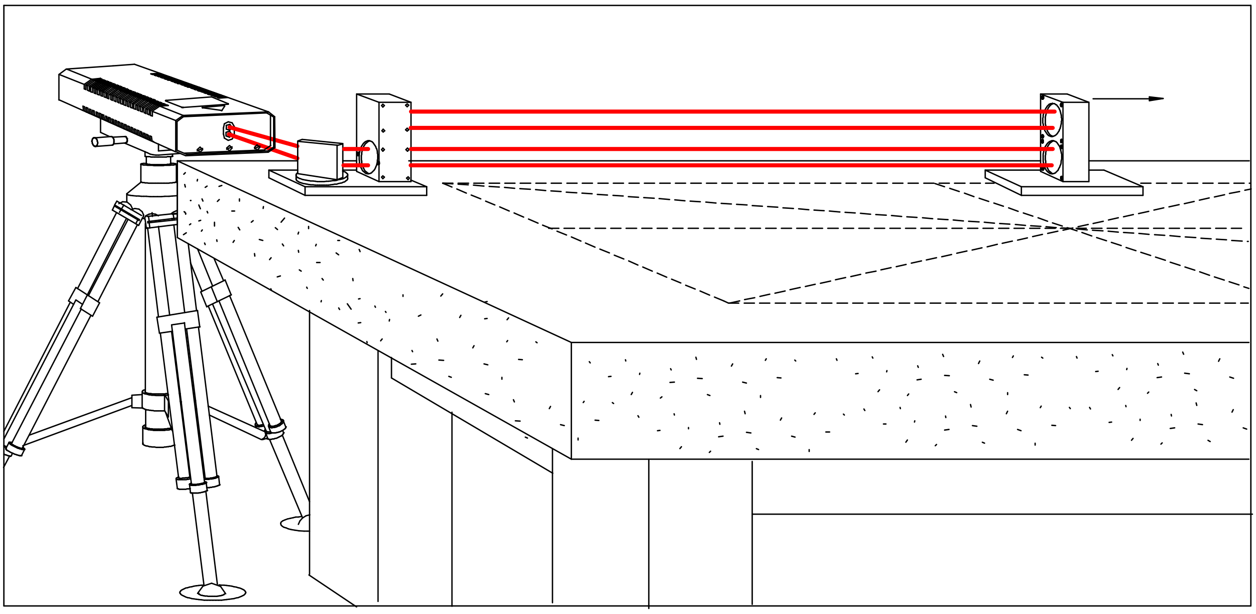


Fig. 8: Measuring setup at a surface plate

Assembly

The optical and mechanical modules and components of the equipment are shown by Fig. 9. Fig. 10 illustrate their assembly.

Flatness interferometer

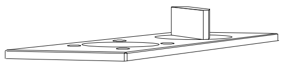
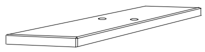
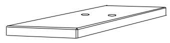
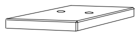
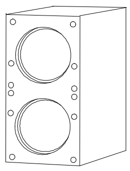
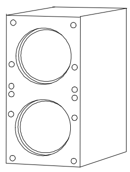
Base plate with turn mirror 118 269302-4015.524		Quantity: 2
Base distance plate 150 269302-4011.625		Quantity: 1
Base distance plate 100 269302-4011.725		Quantity: 1
Base distance plate 50 269302-4011.825		Quantity: 1
Angle interferometer 114 269302-4015.324		Quantity: 1
Double corner reflector 115 269302-4015.424		Quantity: 1

Fig. 9: Optical and mechanical modules and components – Flatness measurement

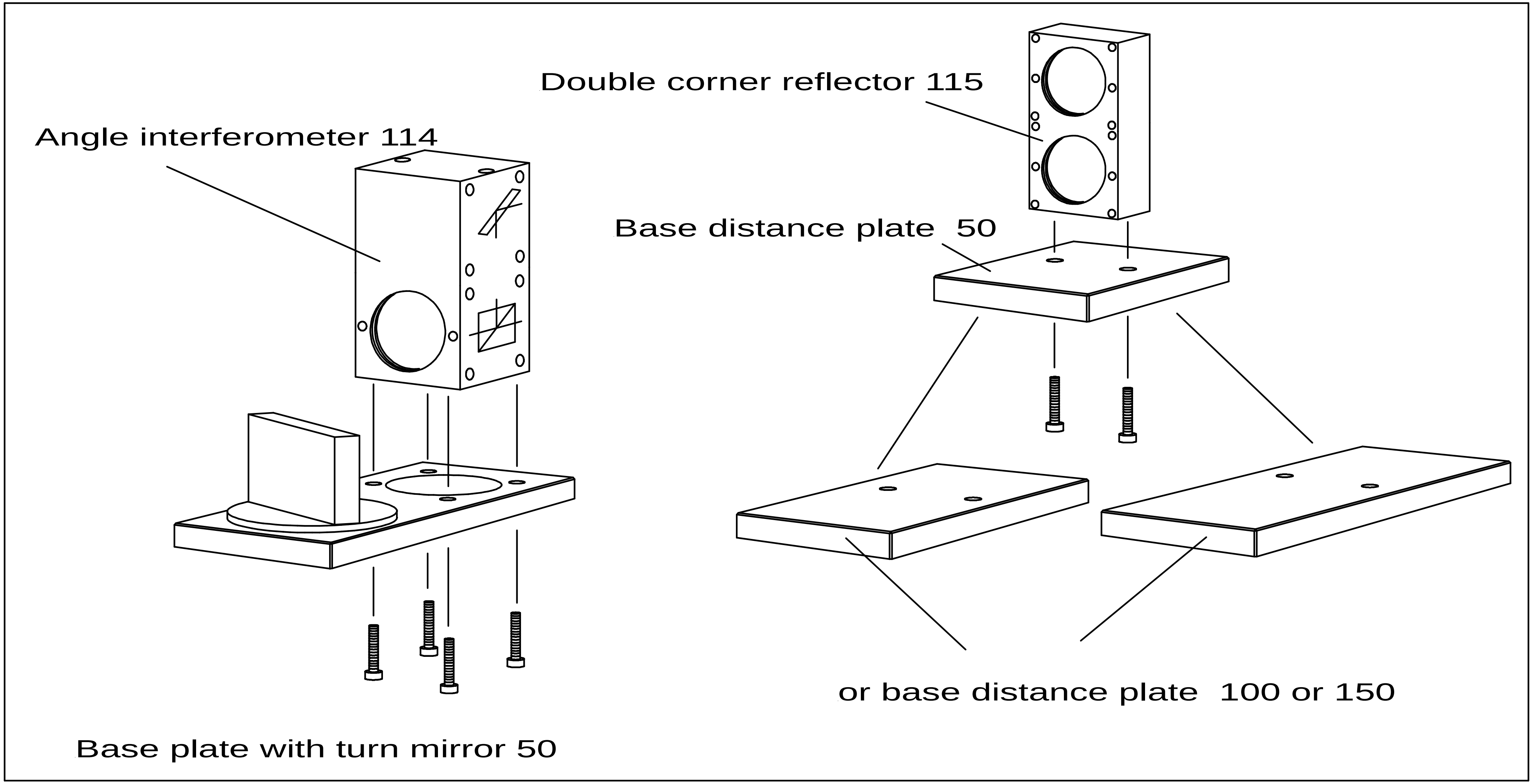


Fig. 10: Mounting assembly flatness measurement

Measurement assembly

With all modules and components assembled, the configuration consisting of **Laser measuring head – Angle interferometer and Double cube corner reflector** can be set up on the object to be measured. The setting-up procedure should follow the sequence of steps described below:

1. Identify the position of the measuring plane to the laser beam.

2. Find a stationary reference point in line with the axis of movement
   alignment the measuring axis over Base plate with turn mirror, Angle interferometer and Double cube corner reflector

Important

The optical modules must be so located that the point of location on the motion axis, the stationary reference point of fixing the Angle interferometer, the Double corner reflector and the beam exit port of the laser head can be aligned on a line in parallel with the motion axis (Fig. 11).

3. Fix the optical modules at the locating points found, wherever possible, in order to reduce measurement errors

Angle interferometer	stationary reference point (2)
Double corner reflector (Measuring mirror)	movable reference point (1)

Important

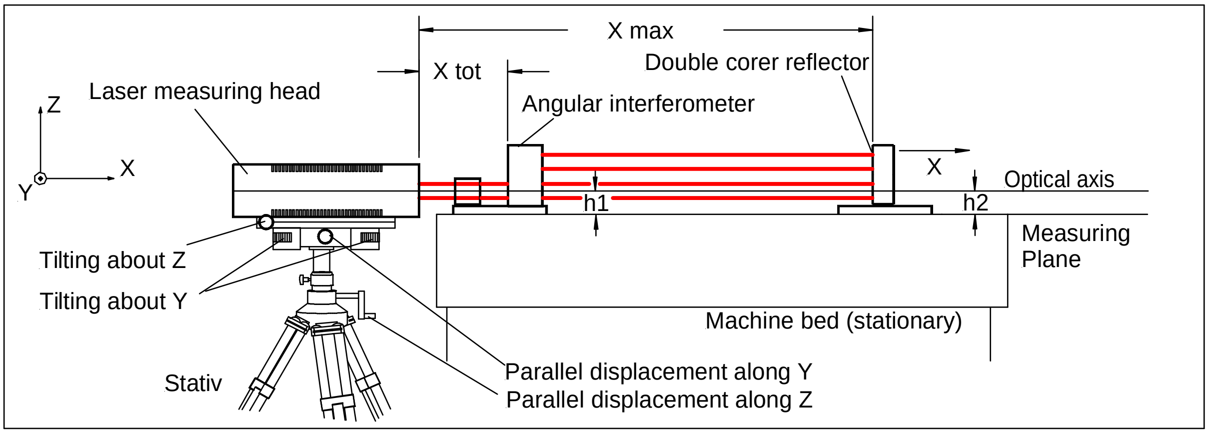
Angle interferometer and Double corner reflector must have equal distances to the measuring line (h1 = h2 in Fig. 11) in order to avoid angular errors.

4. Roughly align the laser beam with the optical axis of the installed optical modules.

Tips:

(1) Position the laser head as closely as possible to the interferometer.
(2) Position the Double corner reflector at the most distant point possible from the interferometer.
(3) Check whether the adjustable table is at the centre of its parallel displacement and tilting ranges. ⇨ This is important to ensure sufficient freedom of adjustment both ways during fine alignment of the beam path.

Fig. 11: Measuring setup, optical path



5. Fine alignment of the beam path

Tip

To facilitate the alignment of the optical path in parallel with the measuring axis, remove the interferometer from the beam path, leaving only the Double corner reflector. ⇨ That way, only one beam returns to the laser head, which makes it easier to assess the state of alignment.

After this, putting back the interferometer into the beam path. Now can start the fine alignment.

A fundamental distinction is made (Fig. 12) between:

- positional alignment (Δy, Δz) (parallel displacement along y and z)
- directional alignment ($\Delta\phi y$, $\Delta\phi z$) (angle tilting about y and z)

The ZLM 700 is designed so that both adjustment facilities are provided on the adjustable table / tripod assembly. The merit of this arrangement is that you do not have to constantly alternate between two adjusting locations (laser head - measuring reflector).

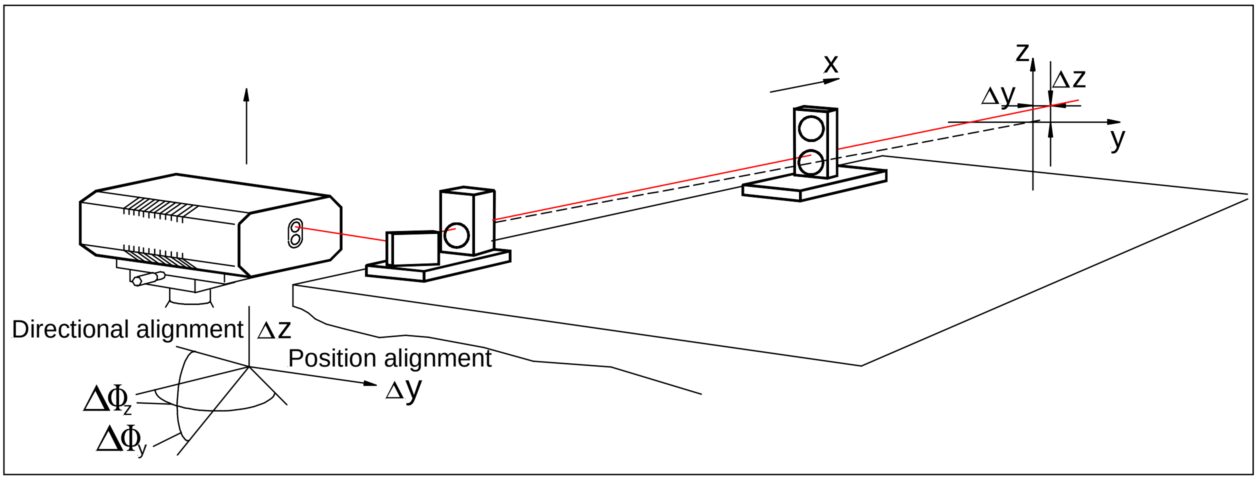


Fig. 12: Alignment of the beam path

The location of the Double cube corner reflector relative to the Angle interferometer is important for both positional and directional alignment:

Positional alignment, Parallel displacement	⇨	at the Double cube corner reflector position nearest to the laser, Fig. 13
Directional alignment, tilting position	⇨	at the Double cube corner reflector most distant from the laser head, Fig. 14

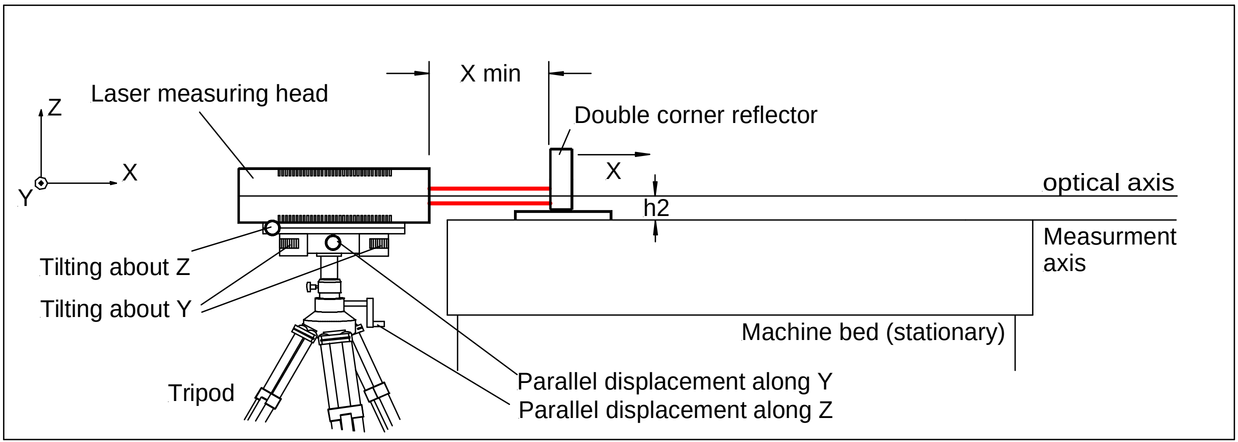


Fig. 13: Positional alignment

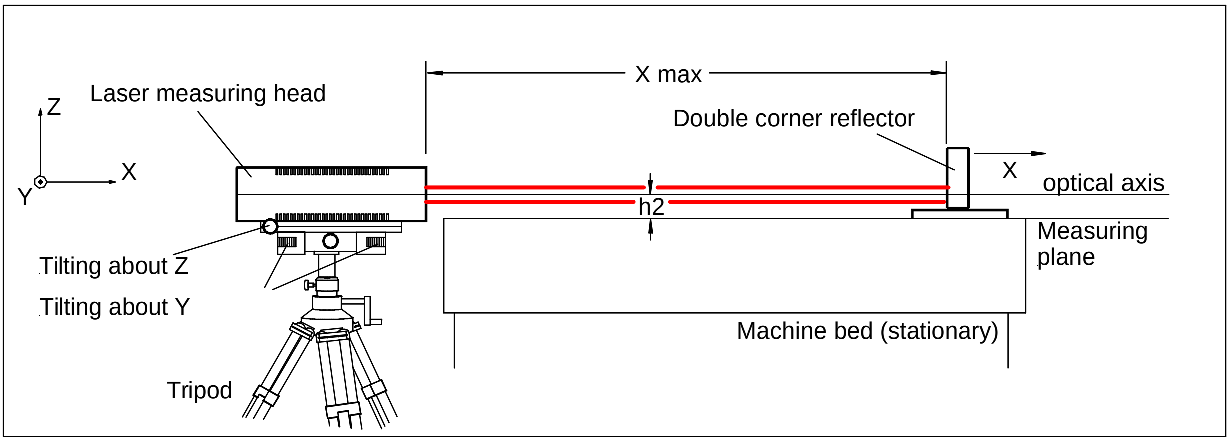
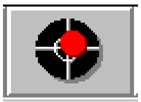


Fig. 14: Directional alignment

Adjustment

From these basic principles, the following procedure of aligning the beam path results:

1) Select menu item  in the "Measurement" program routine.
   In this menu item, the powers of the two beams reflected back into the laser head (reference and measuring beams) are represented by two spots on the monitor screen. The screen graph immediately shows the effect of alignment manipulations and thus allows the quality of alignment of the two beams to be checked and optimized.

2) Move Double cube corner reflector to the point most distant from the laser head and fix it there (Fig. 14). Adjust the laser beam direction in y and z:
   $\Delta\Phi y$ - Turn the two lateral knurled screws of the adjustable table;
   $\Delta\Phi z$ - Turn the two knurled height adjustment screws of the adjustable table.

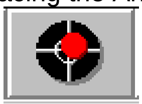
   Align until the reflected beam hits the beam entrance port of the laser head.
   For fine alignment, use the cross-lines shown on the screen.

3) Move the Double cube corner reflector to the point closest to the laser and fix it there (Fig. 13).
   Adjust the laser position in y and z:

   Δy - Turn the micrometer screw of the adjustable table to displace the laser in parallel.
   Δz - Turn the height adjustment handwheel of the tripod.

   For fine alignment, use the crosshairs presented on the screen.

   Repeat steps 2 and 3 alternatingly until no significant change in beam position (relative to the screen cross-lines) can be noticed.
   The permanent angular error between the optical and mechanical axes can be seen as the blue moving bar below the cross-lines presentation.

4) After beam path alignment, align the angle interferometer with the beam path by the following steps (Fig. 12)
   - Fix the angle interferometers on the measuring grid line for the first straightness measurement.
   - The mechanical mounting height need not be adjusted (height is equal to that of the Double corner reflector).
   - Effect lateral fine alignment of the beam path by displacing the Angle interferometer, checking the quality of alignment by the screen mode 

IMPORTANT

Pay attention to the same local situation of the points of measuring and reference beam in the cross-lines.
(importantly for perfect interferenc signal)

Please note!

The adjustment of the optical components on another measuring line is carried out with the Turn mirror to the Angle interferometer. If this procedure is no longer possible, then the laser measuring head must put and the beam path must be adjusted newly to the measuring level, described like in this chapter.

Aligning the interferometer completes the alignment of the setup, which is now ready for measurement (see the Software Manual).

H Focus - Touching

At this kind of interferometer the light of the measuring arm of the interferometer can focalized by means of a converging lens directly on a measuring object.
This makes it possible to use very small mirrors or reflective surfaces. Though so can be measured only in a movement area of approximately ±0.2 mm. Therefore the focus-touching is particularly suitable for measuring small movement sequences of operations (e.g. piezo actuators), concentricity measurement at reflective objekts and to vibration measurement.

The optics modules required for the focus-touching are:

1	***Polarizing beam splitter 101***	***269302-4010.124***
1	***Cube corner reflector 102 (as reference reflector)***	***269302-4010.224***
1	***Vibrometer ancillary lens 320***	***269302-4006.424***
1	***Plane mirror reflector small 317 (as measuring reflector) or a reflecting object surface***	***269302-4010.324***

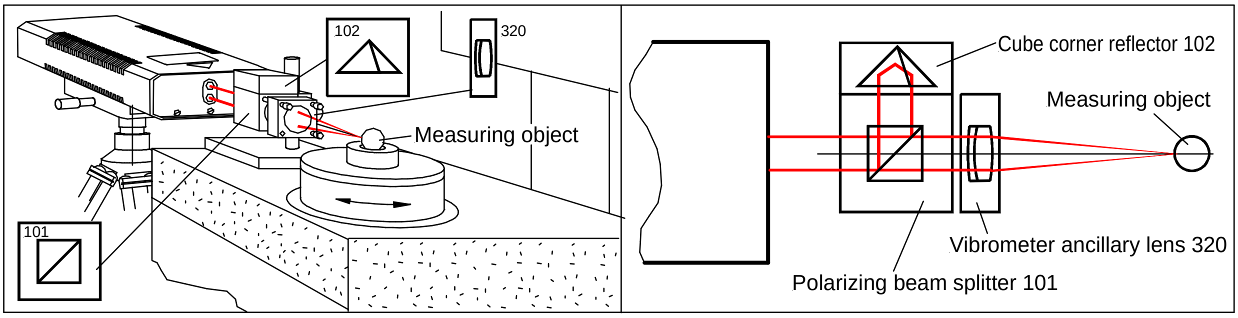


Fig. 1: Optical scheme of focus-touching (concentricity measurement with measuring ball)

Functional description

The light emerging from the laser head serves as the measurement beam, which passes an interferometer arrangement with lens attachment, followed by a measuring and a reference reflector, and strikes a detector E1.
Because of a polarizing beam splitter in the interferometer, the measuring reflector only receives light of frequency f1, while the reference reflector only receives light of frequency f2.
With the measuring reflector at rest, E1 detects the laser's differential frequency (f1 - f2 = 640 MHz), which is equal to the electronic reference signal (E2) detected in the laser head. As the measuring reflector is displaced, the beam portion of frequency f1, reflected by this reflector, is Doppler-Shifted by ±df1. Accordingly, detector E1 registers a measuring frequency of Δf + df1 or Δf - df1, depending on which way the measuring reflector is moved. 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 speed of the measuring reflector, from which the displacement of the measuring reflector is computed by integration (Fig. 2).

The **Resolution** of this interferometer with focus-touching is **2,5 nm.**

The **Movement range** is ± **0,2mm**

The **Focal length** of vibrometer ancillary is **200 mm** (distance between lens centre to the focus is **196,12 mm**).

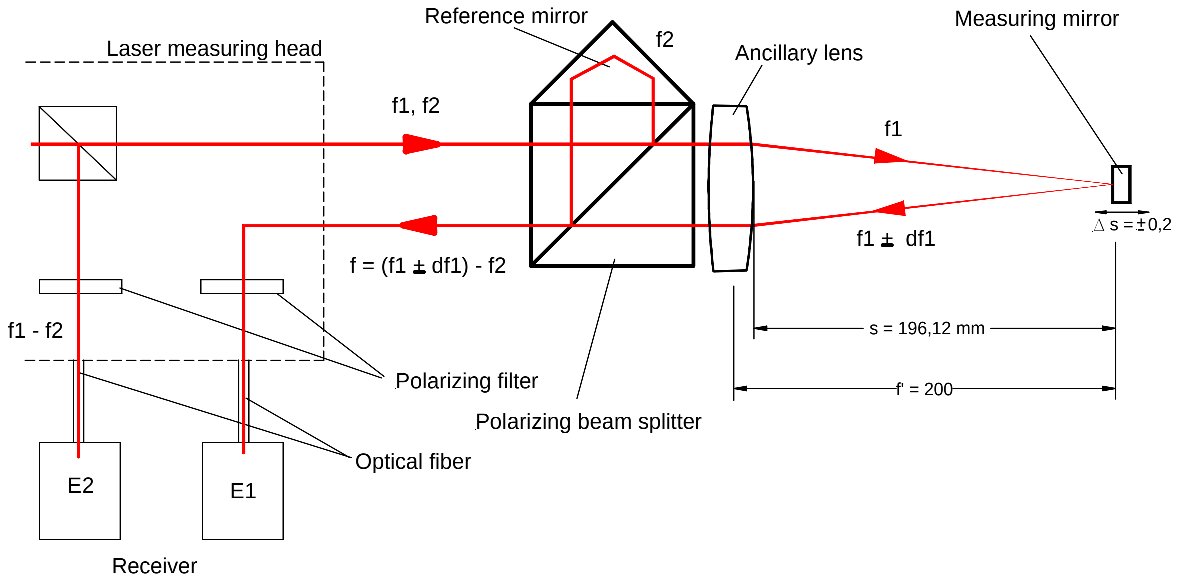


Fig. 2: Operating principle of the focus-touching

Assembly

Fig. 3 shows the optical and mechanical modules and components that make up a Cube corner reflector interferometer with lens attachment (2.5nm-resolution).
Fig. 1 presents the overall configuration of the functional system (the tripod and the adjustable table are not shown). Fig. 4 depicts the assembly of the modules and components, and Fig. 5 illustrates a practical application. Thanks to the system's modular design, other setups are also possible. For the contents of the transport cases and the placement of the components therein, see Fig. 4 in section "System Description and Operation".

Cube corner interferometer with lens attachment (2.5 nm resolution)

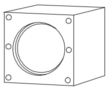
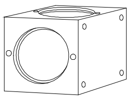
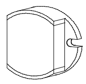
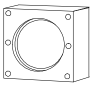
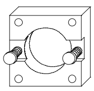
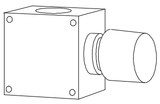
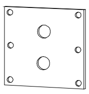
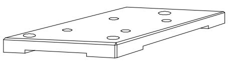
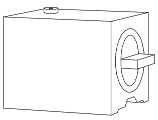
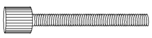
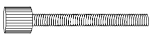
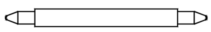
Cube corner refelector 102 269302-4010.224		Quantity: 1
Polarizing beam splitter 101 269302-4010.124		Quantity: 1
Plane mirror reflector small 317 269302-4016.124		Quantity: 1
Vibrometer ancillary lens 320 269302-4006.424		Quantity: 1
Adjusting plate 269302-4006.425		Quantity: 1
Clamping fixture 507 269302-4010.325		Quantity: 1
Beam stop plate 516 269302-4014.210		Quantity: 1
Mounting plate 504 269302-4014.410		Quantity: 1
Magnetic base 506 260298-3000.128		Quantity: 1
Column pin 140 260297-9900.128		Quantity: 1
Set of screws 269302-4005.624		Quantity: 1
Knurled screw 36 269302-4011.325		Quantity: 2
Spacing jig 269302-4014.825		Quantity: 1

Fig. 3: Optical and mechanical modules and components for Focus-touching

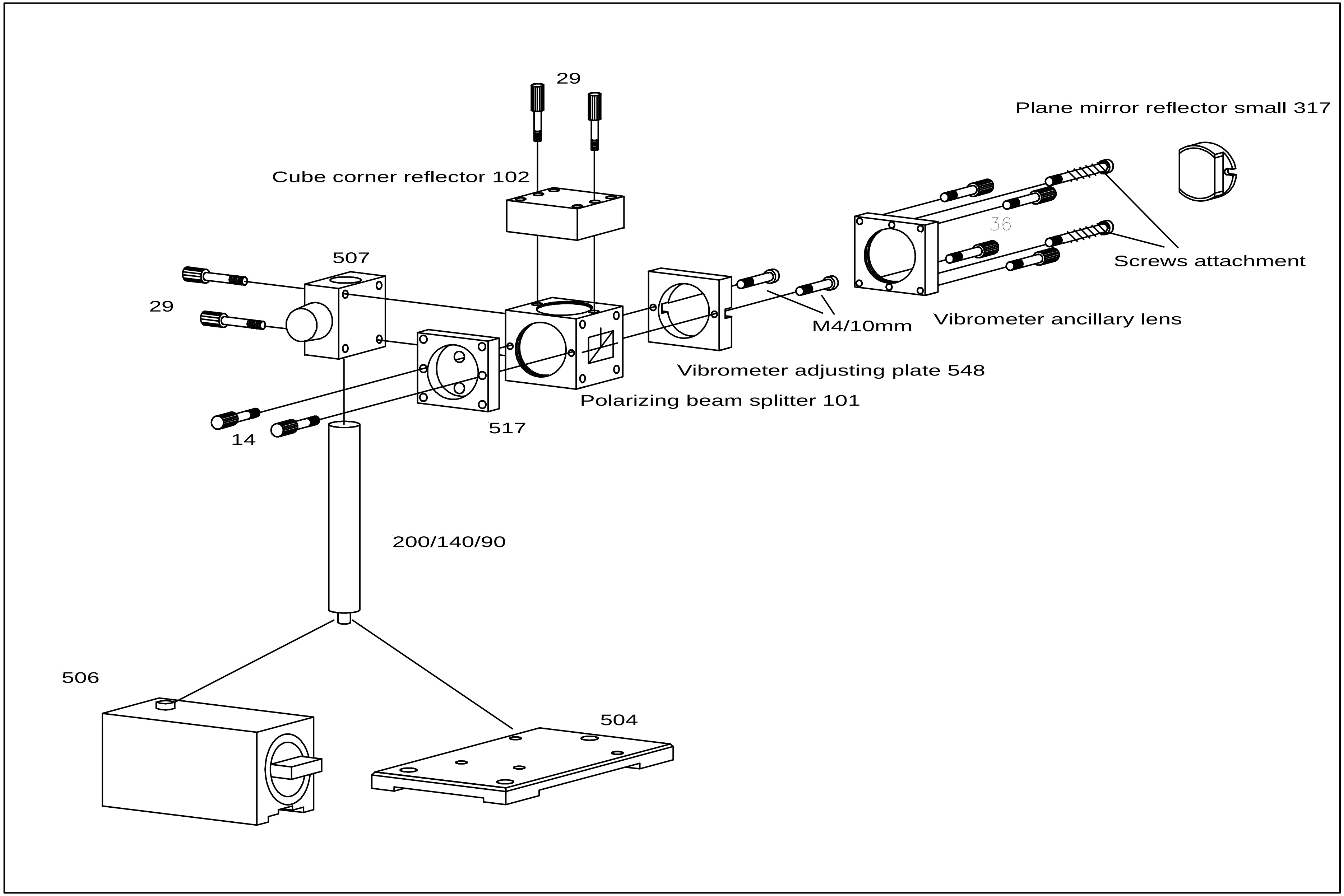


Fig. 4: Assembly of optical and mechancial components

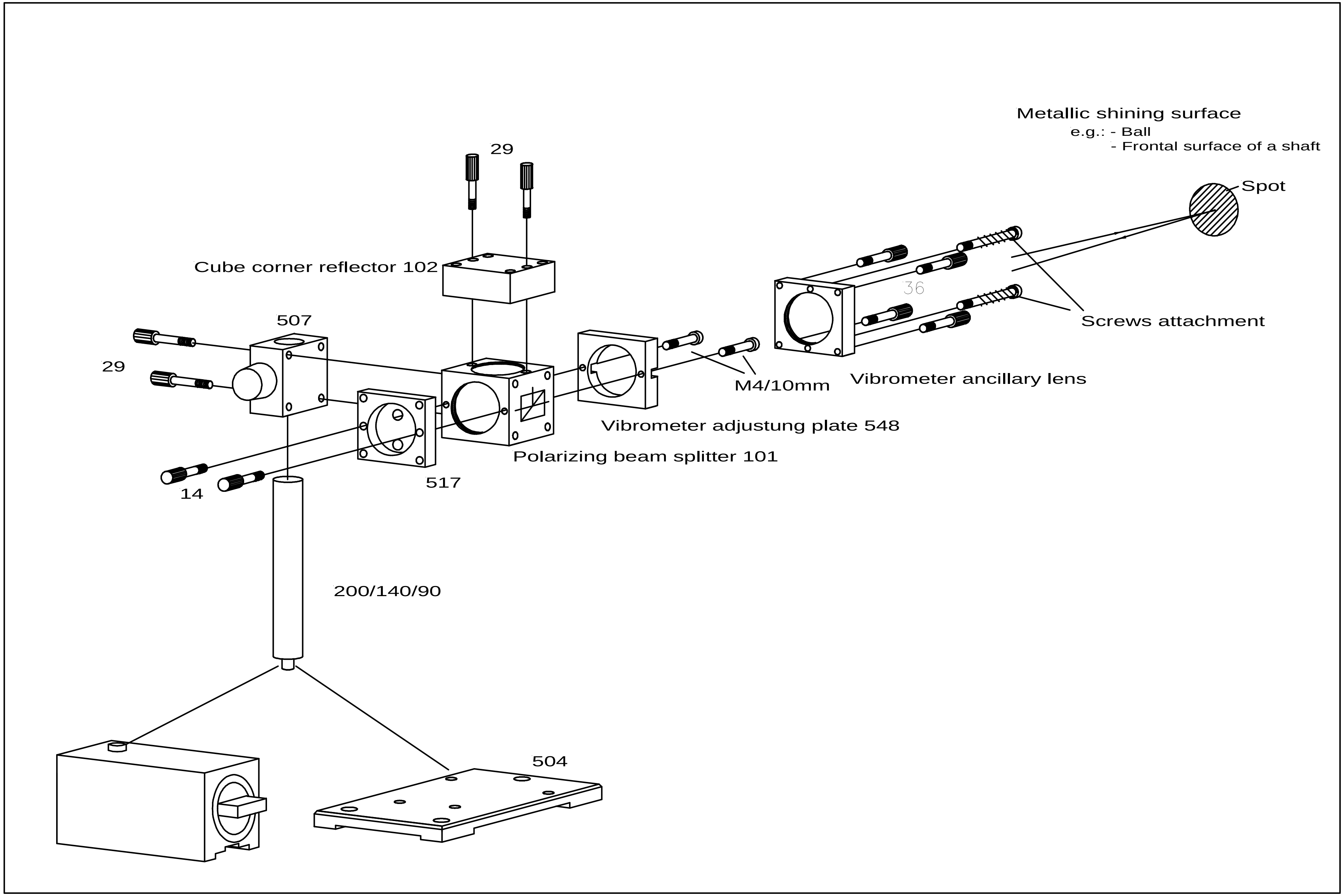


Fig. 5: Assemply of optical and mechanical components

Measurement assembly

The Vibrometer ancillary lens can be fastened with the Vibrometer adjusting plate directly at the interferometer. The jadjustment is carried out via four knurled screws 36. For the complete measuring mounting from **Laser measuring head** - **Interferometer with ancillary lens** - **Plane mirror reflector** should go on in following steps:

1. Identify the axis of motion to be measured and find a location on the moving part of the object where the optical system can be fixed (1).
2. Find a stationary reference point in line with the axis of movement (2).
3. Mind the focal length of the lens attachment (about 200 mm). The spacing between the lens centre and the reflecting surface should thus be S = 196,12 mm.

Tips:

(1) Position the laser head as closely as possible to the interferometer.
(2) Check whether the adjustable table is at the centre of its parallel displacement and tilting ranges. ⇨ This is important to ensure sufficient freedom of adjustment both ways during fine alignment of the beam path.

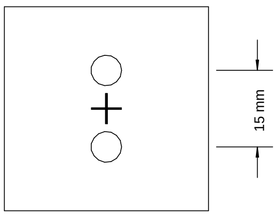
4. Fix the optical modules at the locating points found, wherever possible, in order to reduce measurement errors:

Interferometer with ancillary lens	stationary reference point (2)
Plane mirror (measuring) reflector	movable reference point (1)

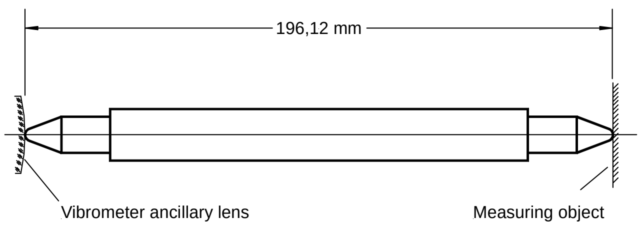
IMPORTANT:
The laser beam hits the reflector by 7.5 mm put to it centre.
Only by the Vibrometer ancillary lens the beam is reflected to the centre of the reflector.

For the adjustment there are the following aids:

Target mark
A tarket mark can make the adjustment easier.
At this the cross is put to the place where the laserspot debit arrive. Ohne Vorsatzlinse wird der Laserstrahl auf den oberen Kreis ausgerichtet. Without vibrometer ancillary lens the laser beam is aligned with the upper circle.

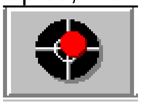


Spacing jig
Serve to adjust to gap
Measuring object - Lens top



Adjustment

From these basic principles, the following procedure of aligning the beam path results:

1) *Select menu item*  *in the "Measurement" program routine.*
In this menu item, the powers of the two beams reflected back into the laser head (reference and measuring beams) are represented by two spots on the monitor screen. (With correct aligning procedure, i.e. with the interferometer removed, both the measuring and reference beams fall on the reflector.) The screen graph immediately shows the effect of alignment manipulations and thus allows the quality of alignment of the two beams to be checked and optimized. Because of the short stroke of the reflector, the screen graph does not help much for minimizing the cosine error. This should rather be attempted before, when positioning the laser head to make the beam parallel to the axis of motion. The screen graph is useful, however, for optimizing the positions of the two beams relative to the cross-hairs, i.e. making them coincide and positioning them so that they best hit the beam entrance port of the laser head.

2) Adjustment the distance of the Ancillary lens to the Plane mirror reflector:
The the fine adjustment between Ancillary lens – Plane mirror reflector is carried out via the 4 knurled screws against the springs of the 2 inside hexagon screws of the Vibrometer adjusting plate. To this the spacing jig can be used.
If the distance between lens and plane mirror reflector is equally the focal length of the lens, the measuring beam is represented on the screen and can be adjusted optimally to the cross-lines after this representation.

IMPORTANT:

Pay attention to the same local situation of the points of measuring and reference beam in the cross-lines.
(importantly for perfect interferenc signal)

Aligning the interferometer completes the alignment of the setup, which is now ready for measurement (see the Software Manual).

Examples of measuring set-ups

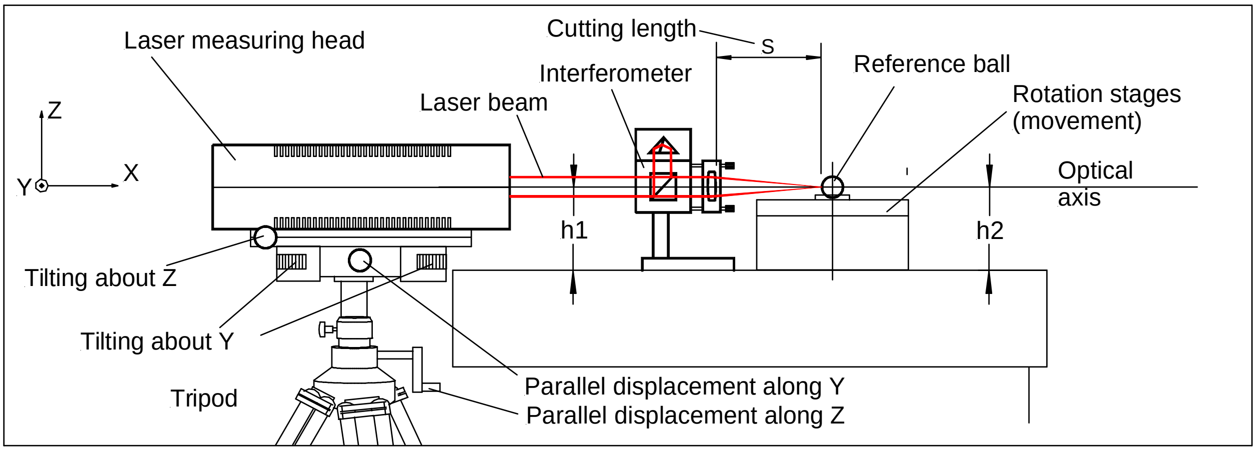


Fig. 6: Radially measurement of a rotary stage (example 1)

Explanation:
A precision glass ball with mirror coating is the reference for the measurement of the radial deviation of a rotary stage. This is centrically attached on the rotatory stage. The beam is focussed after the Ancillary lens and arrives the ball equator as a point. The beam is reflected in the same angle. Expanded by the lens the beam reaches the interferometer.
The beam axis must oriented square to the axis of rotation of the ball. The reference ball cannot be adjusted absolutely exactly to the axis of the rotatory stage. The measuring is overlaid a periodical (by 360°) sinusoidal adjustment error. This adjustment error must be eliminated by software.

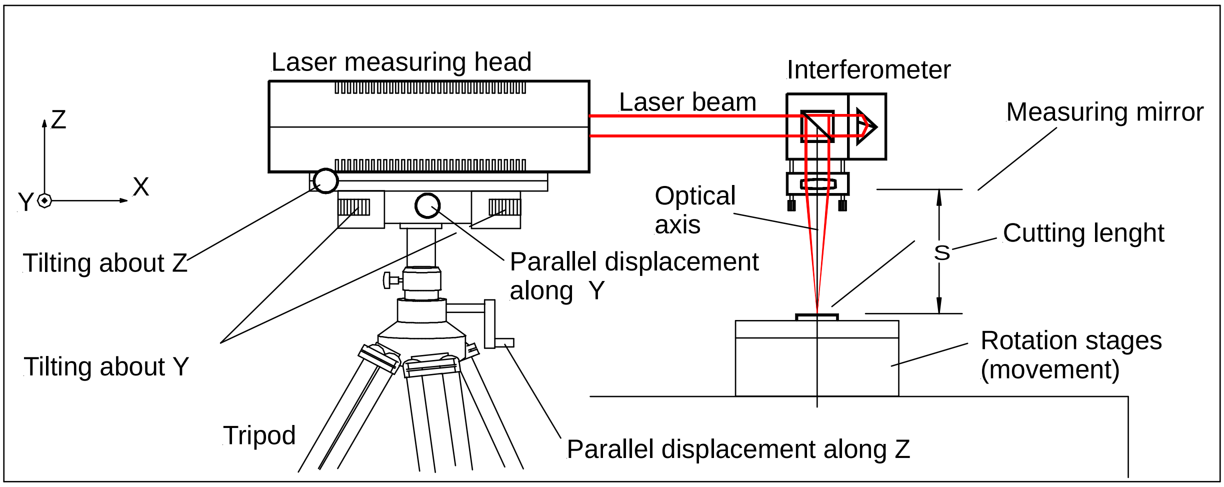


Fig. 7: axially measurement of a rotary stage (example 2)

Explanation:
A Plane mirror is attached to the measurement of the axial deviation of a rotatory stage. The unit interferometer with ancillary lens is fixed centrically. The tilting of the plane mirror to the rotary axis cannot adjust exactly. It is required to eliminate the adjustment error by a careful adjustment of the focus position on the centre of axis.

I Multi-Axial Configurations 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 ar e 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 caliper. A maximum of accuracy is reached (also at possible pitch movements of the xy-stage.

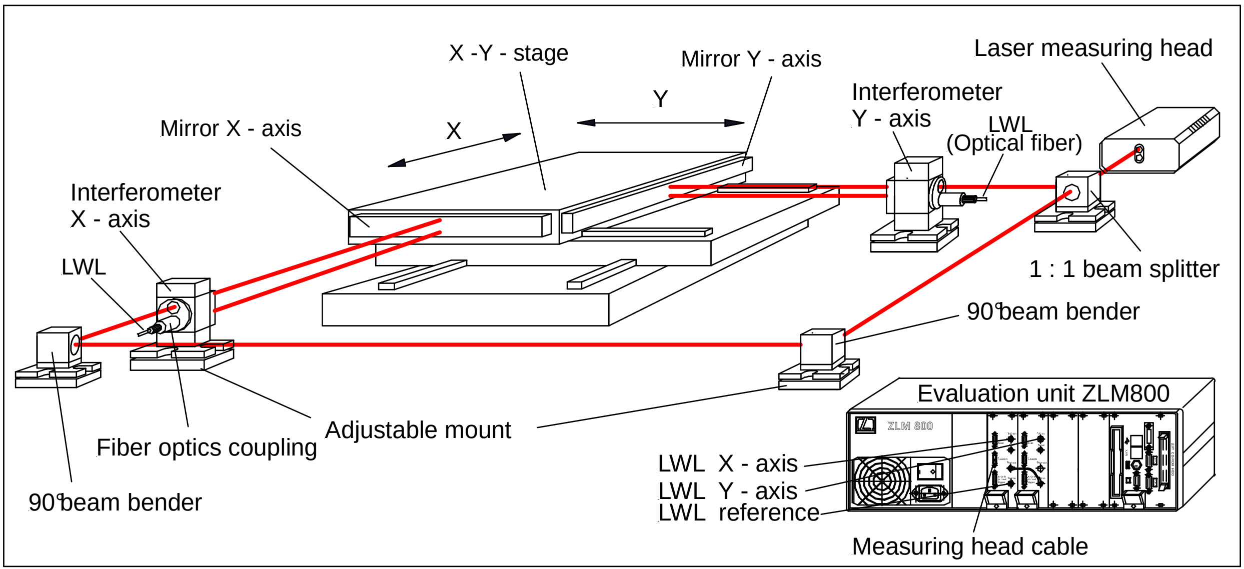


Fig.1 : Build-up of a two-axis systems with plane mirror interferometers

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.

1.1. Optical modules for beam control and beam splitting

At the beam control of multiaxis-systems 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.

Therefor 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

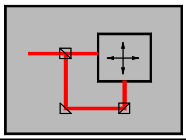


Fig. 2:
90° Beam bender 110
for double beam,
dielectrically polarization neutral mirror coating
Order - No.: 269302-4011.024

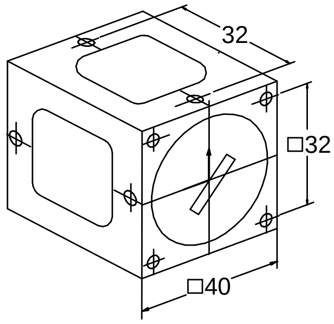
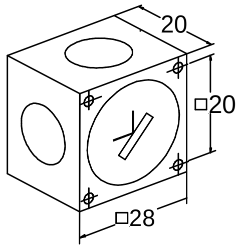


Fig. 3:
90° Beam bender 205
for single beam,
dielectrically polarization neutral mirror coating
Order - No.: 269302-4012.424



1.1.2. 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*

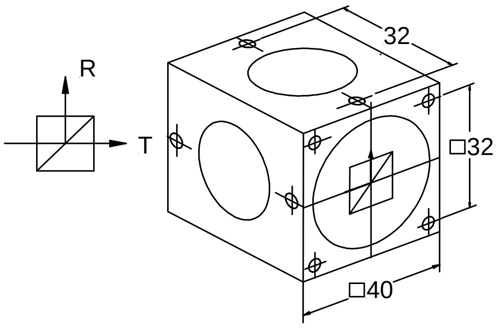
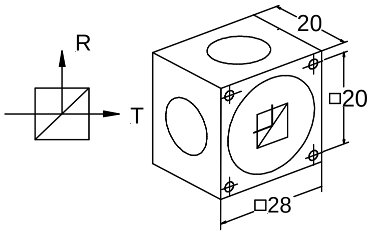


Fig. 5:
Beam splitter B
for single beam,

Order - No.: *see into the table*



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

1.1.3. Interferometer

The module system of ZLM700/800 offers a variety of build up possibilities (fig.s 10a,b,c). At this a machine part (measuring level) is moved opposite the stationary machine part (reference level).
The correct position as well as the tilting of the measuring level shall be measured at this opposite the reference level into two axes.

Fig.10a: shows a measuring build up, - consists of standard components

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

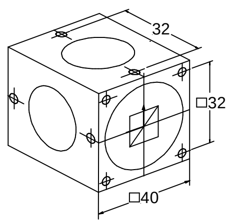


Fig. 7:
Cube corner reflector 102
Order-No.: 269302-4010.224

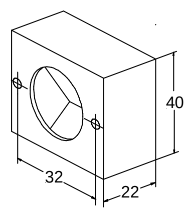


Fig. 8:
λ/4 – Plate 104
Order-No.: 269302-4010.424

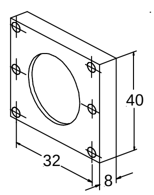
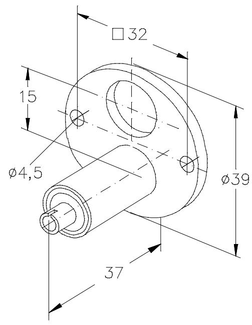


Fig. 9:
Fibre optics coupling 222
for Polarizing beam splitter 101
Order-No.: 269302-4015.724



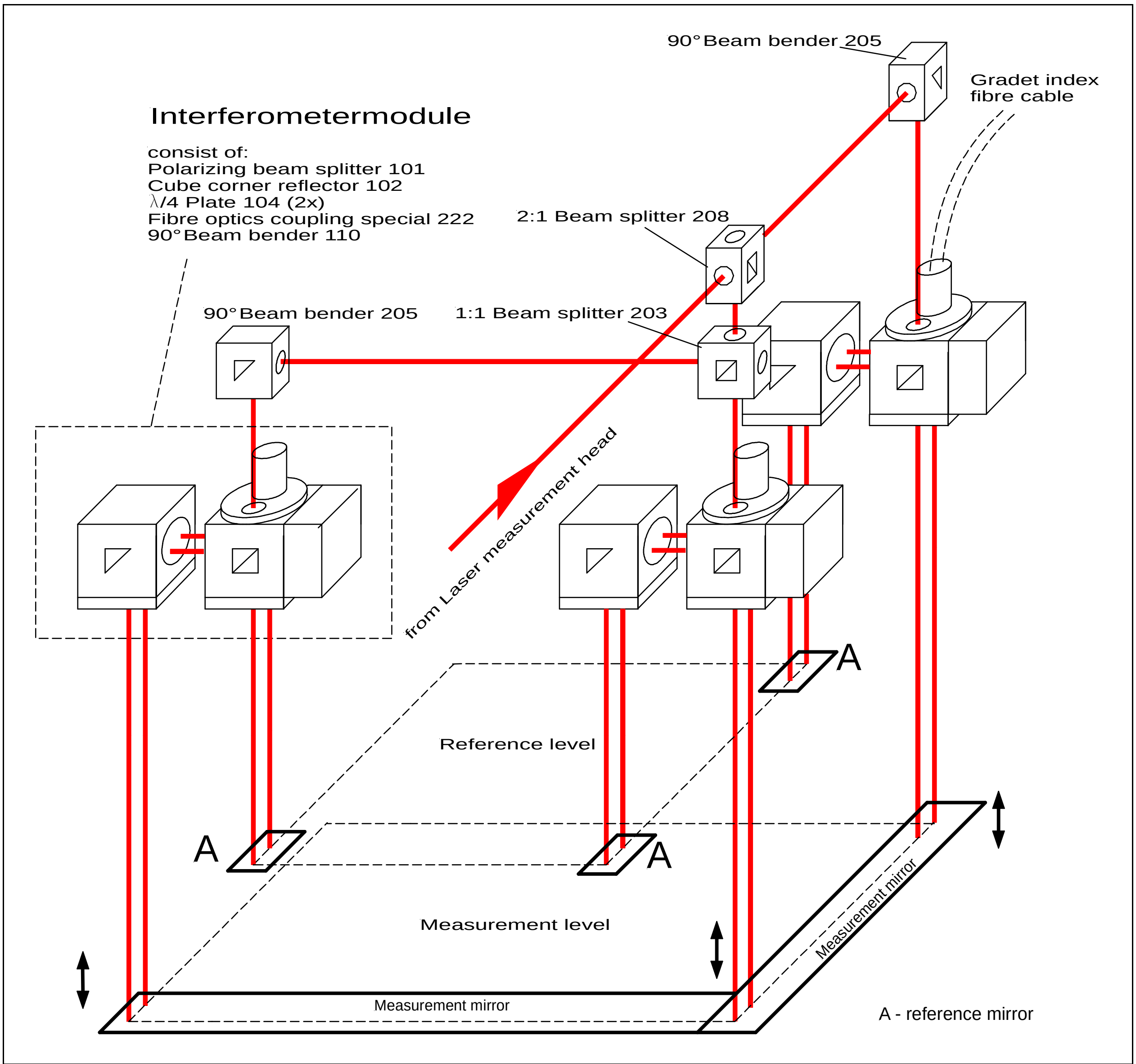


Fig. 10a: Multi-axis-measuring system (3axes interferometer with standard modules)

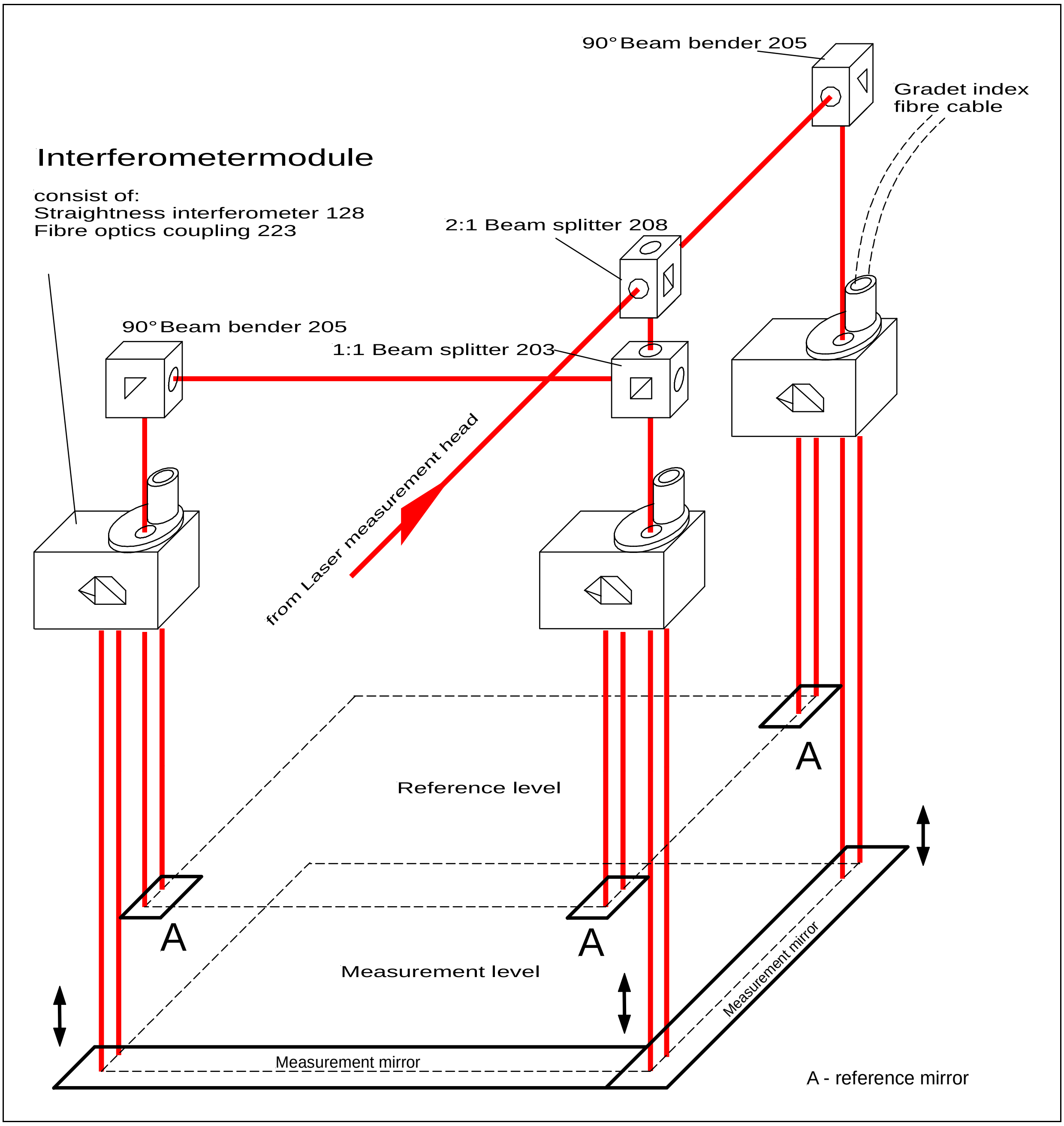
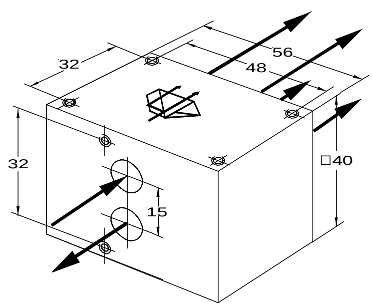
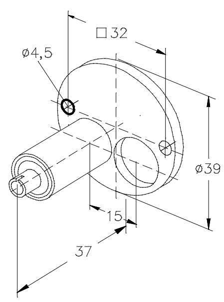


Fig. 10b: Multi-axis-measuring system (3axes interferometer with Straightness interferometer)

Fig. 11:
Straightness interferometer 128
Order-No.: 269302-4012.824



Fibre optics coupling 223
for Straightness interferometer
Order-No.: ***269302-4015.824***



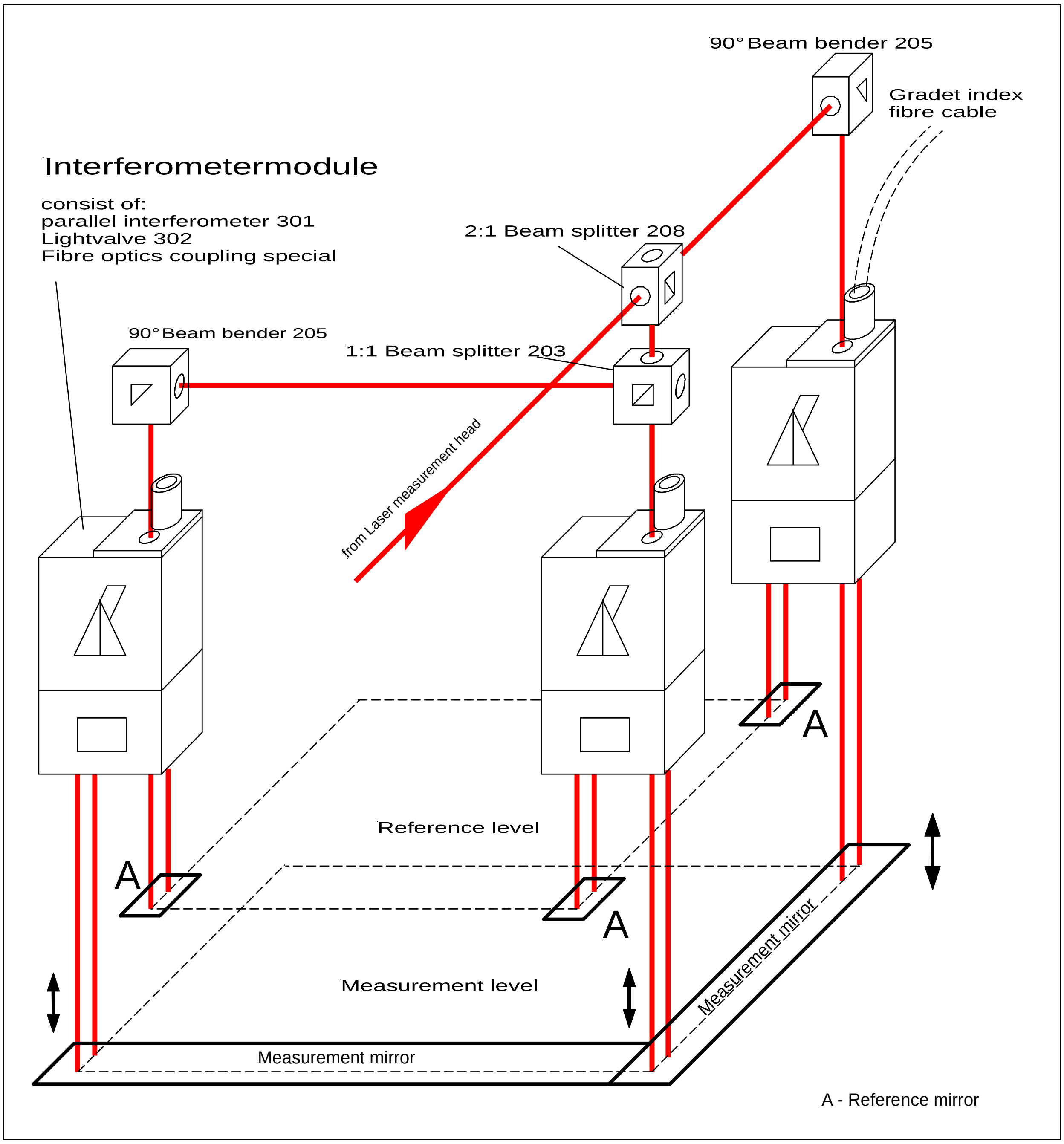


Fig. 10c: Multi-axis-measuring system (3axes interferometer with Parallel interferometer)

Fig. 12:
Parallel interferometer 301
(„Kösters“ – Interferometer)
***Order-No.:* 269302-4013.324**

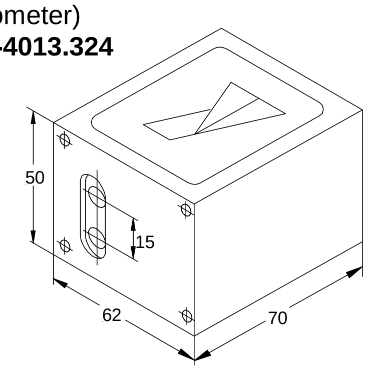
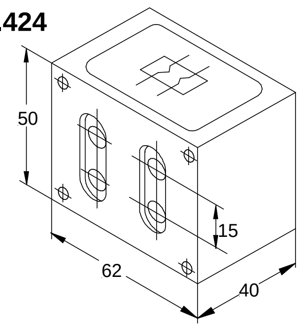


Fig. 13:
Light valve 302
(only in connection with parallel interferometer applicatively)
***Order-No.:* 269302-4013.424**



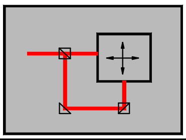
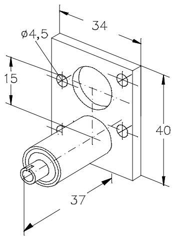


Fig. 14:
Fibre optics coupling 224
for Parallel interferometer 301
Order-No.: 269302-4015.924



1.2. Functional description of the Parallel interferometer

The part of the laser light branched off from the intensity divider as measuring beam is directed to the Kösters prism (figure 2) where it is divided on the dielectric separating layer into its two partial beams polarized in mutually perpendicular planes. One partial beam is reflected in the direction of the measuring mirror, while the second beam is reflected in the direction of the comparison mirror. They emerge parallel from the Kösters prism and pass through two plane plates before they enter the so-called light valves. 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. The light valves consist of a polarization-optical beam-splitter which is combined with a triple prism. Rectified and polarized, both partial beams now enter a light valve each where they pass unhindered through the dielectric layer in the beam-splitter, traverse a λ/4 plate and are reflected by the measuring and comparison mirrors back onto themselves. While traversing the λ/4 plate, both linearly polarized partial beams are converted into circularly polarized light. After the reflection of the two partial beams at the plane mirrors and their renewed passage through the λ/4 plate the circularly polarized light again becomes linearly polarized light, but now with the polarization plane rotated 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. But now the vibration 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 2 of AE800.
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. 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. (Fig.s 15, 16)

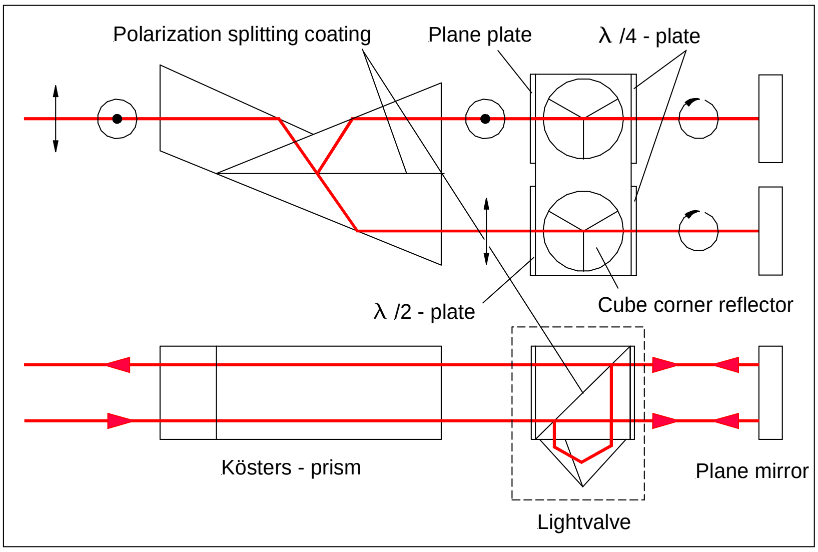


Fig. 15: Parallel interferometer

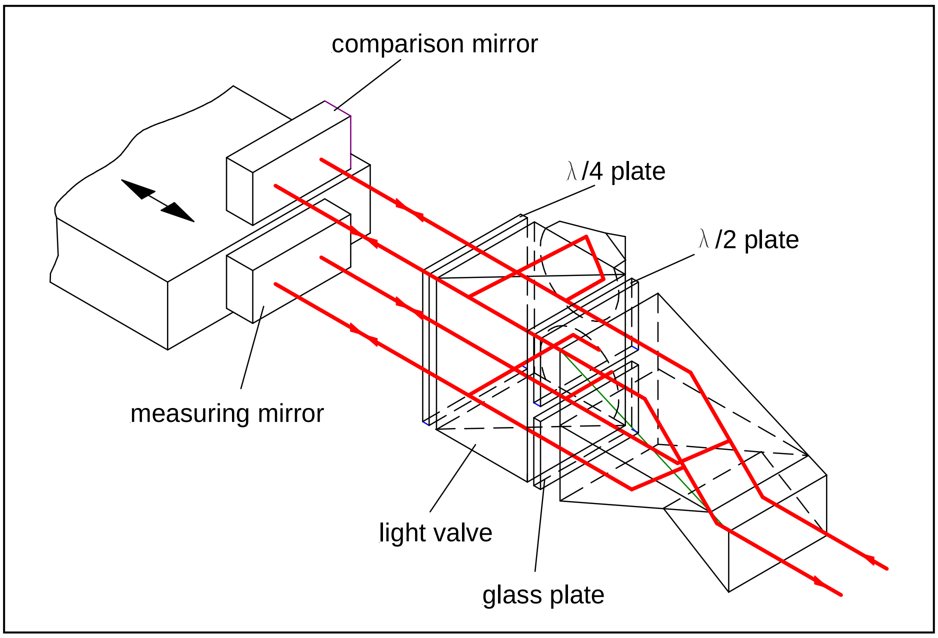


Fig. 16: Schematic diagram of the interferometer optics for difference plane mirror interferometers

1.3. Adjustable mount for optical modules

Following adjustable mounts serve to adjustable mounting the optical modules:

Fig. 17:
Adjustable mount 588 for optical components □ 40
Order-No.: 269302-4009.025

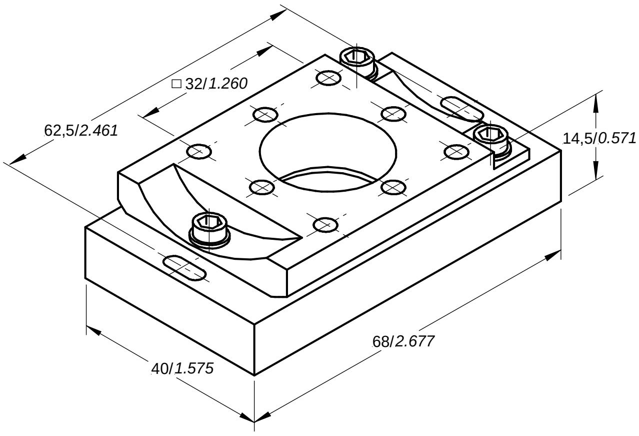
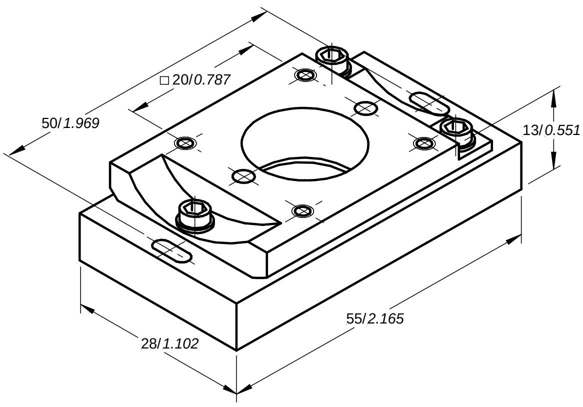


Fig. 18:
Adjustable mount 589 for optical components □ 28
Order-No.: 269302-4009.125



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
- 1 - 4 interpolator assembly (according to quantity off interferometers)
- cPCI/PXI processor insert Pentium III 850 MHz + operating system WINDOWS 2000/XP
- 1 Control unit with RS-232 and CENTRONICS interface
- Interfaces for keyboard, mouse, monitor
Ethernet, LAN, USB1/2, RS 232, IEEE 488 optionally external Disk drive
- Hardware interfaces of interpolator assembly:
  - 32 bit real time count 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 to-zero fill

Fig. 19 show the view and the interfaces of the evaluation unit AE 800 cPCI-PXI.
The interfaces of the frontage can be subdivided into interfaces for the data interchange with other units and interfaces, they are necessary for the operation in laser measuring.

2.1.1 Interfaces for operating the laser measuring system

Laser measuring head	Measuring head cable to the laser measuring head, (for screen mode of the quality of the alignment of reference and measuring beam)
AUK	AUK Connection cable
IF - in	Connections of the Fibre optic cables of each interferometer axis (per axis 1 x)
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 data interchange

Keyboard connection and mouse connection Monitor connection	6-pin Mini-DIN electrical socked (PS/2) and mouse connection
IDE Interface	external connection for a further EIDE – device (Hard disk, CD, disk drive)
Serial Interface	data interchange with external units (2 serial ports RS232) to a superordinated computer
IEEE 488 or SCSI	data interchange with external units (optionally)
IF32 Axis (optionally)	32 Bit-Realtime-Interface f (to get a current position count value in the complement with functions of Reset and Trigger)
A-Q-B counter-input 2. counter	counting of the digital pulses of a Heidenhain-scale (0, 90°, 180°, 270°)
A-Q-B counter-output	serial supply off laser position data (0, 90°, 180°, 270°) for Motion control

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

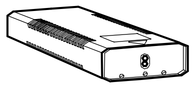
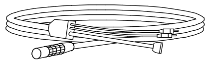
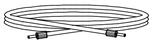
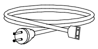
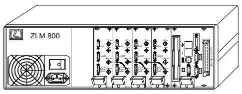
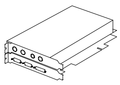
2.2. AE 800 PCI

For standard PCs, industry's PCs and portable PCs there are the possibilities of the equipping:

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

Electrical operating conditions and interfaces are as in the case of the compact PXI variant.

2.3. Equipment

Laser measuring head 269302-4040.026		Quantity 1
Measuring head cable 269302-5041.524		Quantity 1
Grandet index fibre cable 212.678		Quantity 1 per axis
Power cord (DIN-Standard) 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 further one Measuring axis **.../Slave** 269302-5071.526		Quantity 1 Quantity 1 per axis

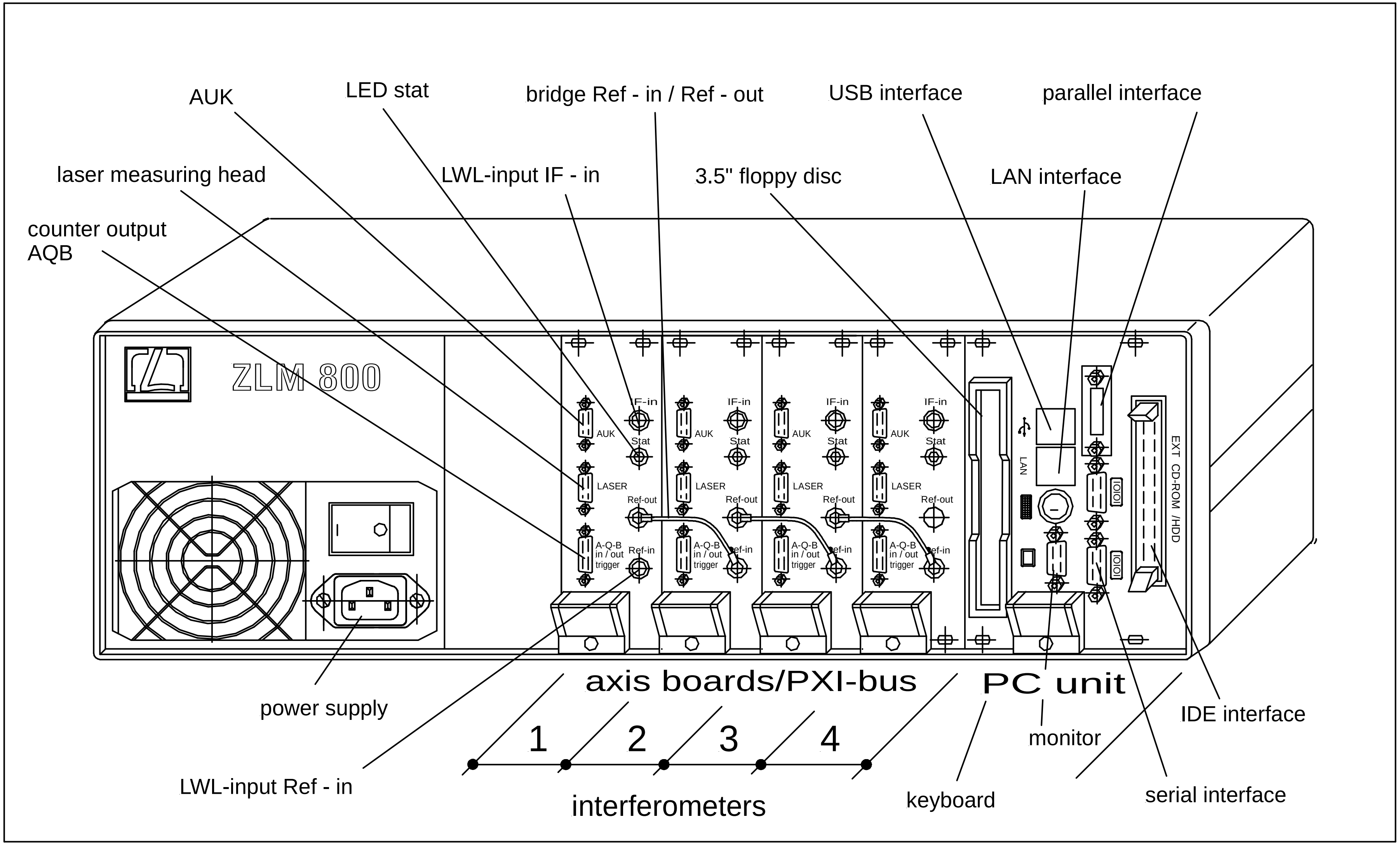
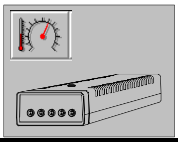


Fig. 19 Evaluation Unit ZLM 800cPCI-PXI



AUK Environmental Sensor

Environmental influences can be compensated in two ways:

1. "Manual" input of the current data for air temperature, humidity and pressure and the material temperature of the testpiece via the PC keyboard.
   This requires regular reading of separate instruments and regular updating of the data entered. In a measuring room, this should be done at least once every day, and in production environments several times a day, in order to obtain a measuring accuracy of **2 µm/m.**

2. Use of the AUK 500 Automatic Environment Detector (*269302-4053.226)* with sensors for air temperature, air pressure and humidity, and facilities for connecting up to five material temperature sensors. The data are automatically updated at an inquiry rate of < 1 Hz. Unless coarse mistakes are made when setting up the Laser Interferometer configuration, (if, e.g., Abbe's comparator principle is maintained), a measuring accuracy of **0.9 µm/m** can be achieved.

Determining the refractive index of the air

In order to reliably and constantly ensure the high measuring accuracy of the ZLM 500 Dual-Frequency Laser Interferometer in non-vacuum operation, it is necessary to continuously record the refractive index of the ambient air and to correct the laser wavelength accordingly. Basically, this can be achieved by three methods:

1. Reading the air temperature, air pressure and humidity off classical analogue instruments, and entering these data via the PC keyboard. The intervals at which readings must be taken depend on the rate at which the air parameters change. This method is the simplest one and will be sufficient in many applications.

   Uncertainty of measurement: 2 µm/m

2. Use of high-resolution sensors (*Parameter method*). In connection with a PC, the sensors automatically sense the temperature, pressure and humidity of the ambient air with a high precision, so that these parameters are constantly updated. As a rule, it is also possible to connect special material temperature sensors for automatically monitoring the temperature of the testpiece or of the entire measurement setup.

   Uncertainty of measurement: 0.6 µm/m

3. Installation of a refractometer (r*eference method*). This is the most expensive method. There is a wide variety of versions to suit the specific application, ranging from "simple" wavelength tracking refractometers to complex multi-chamber vacuum refractometers. They all have in common that refractive index is always measured against an external reference distance and that an extra interferometer channel is needed.

   Uncertainty of measurement: 0.3 µm/m

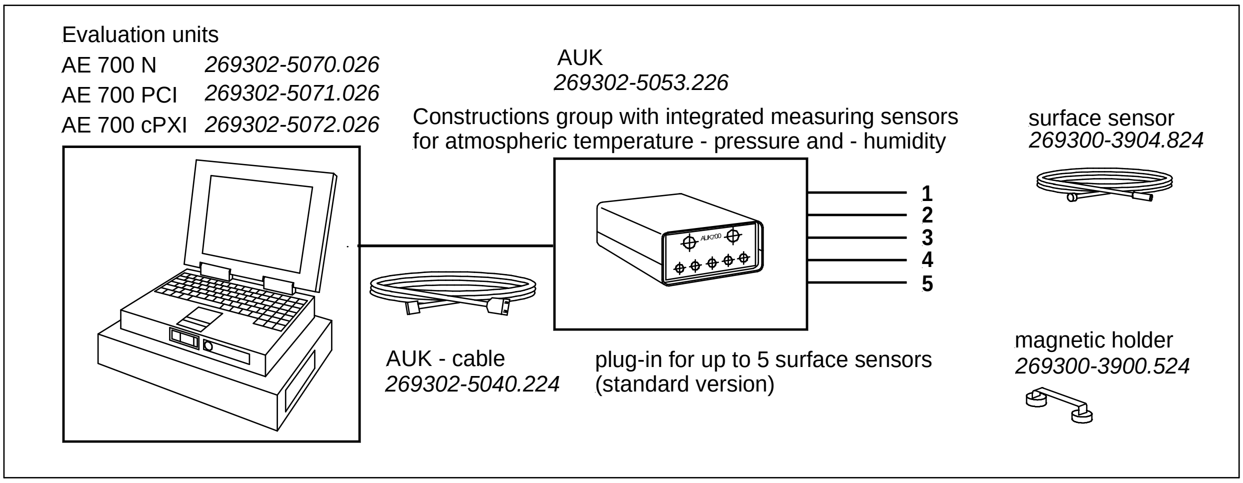
Once the refractive index of air has been identified by one of the three methods, the laser wavelength in air is computed via the equation

$$\lambda = \lambda_o / n$$

where λ : wavelength of laser light in air
λ_o : wavelength of laser light in a vacuum
n : refractive index of air

Design and Mode of Operation

The AUK Environment Sensor operates by the parameter method. The sensors integrated in the unit continuously measure air temperature, air pressure and humidity with high precision and transmit the measured data to the PC. Via the ***Edlen formula*** /1/ the PC determines the refractive index of the ambient air, and from this the current wavelength of the laser radiation.



Edlen's formula applies to humid "standard air" (containing, in addition to nitrogen and oxygen, a content of 300 ppm of carbon dioxide):

$$n = 1 + (2.8793 \cdot 10^{-7} \cdot P) : (1 + 0.003671 \cdot T) - (3.6 \cdot 10^{-8} \cdot P_w)$$

B: *Refractive index of „standard air“*
P: *Atmospheric pressure in hPa*
T: *Air temperature in °C*
P_w: *Water vapour partial pressure in hPa*
100% rel. air humidity at 20°C: 23hPa)

Given the following conditions, which are **typical for a measuring room**,

T = 20℃ ± 1K
P = 1013 hPa ± 10hPa
F = 50% ± 20%

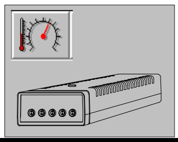
the Edlen formula yields a mean refractive index for the measurement room air of

$$n = 1.0002712 \pm 4 \cdot 10^{-6}$$

The necessity to constantly correct the refractive index is obvious from the amount of variation in refractive index.

The table below shows, for specified measurement lengths and any variations of the air parameters, the amount of apparent length change measured with the laser interferometer as a function of the changing air parameters.

Parameter	**Deviation from measured value**	
Air temperature	- 0.92µm/m/K	$(dn/dT \approx -0.92 \cdot 10^{-6} K^{-1})$
Atmospheric pressure	0.27µm/m/hPa	$(dn/dP \approx +0.27 \cdot 10^{-6} hPa^{-1}$
Air humidity	0.01µm/m/% rel. humidity	$(dn/dP_w \approx -3.6 \cdot 10^{-8} hPa^{-1})$



The Influence of Air Pollutants

The parameter method assumes a standard composition of air. In industrial use, however, the ambient air may contain considerable admixtures of other gases, which are not allowed for by the AUK Environmental Sensor. In order to compute the change in refractive index in such cases, the following table specifies, for the most important gases, the concentration in air that will change its refractive index by $1 \cdot 10^{-7}$:·

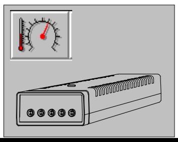
	Specific refractive index n - 1 $(\cdot 10^{-4})$	Concentration in air required for $dn = 1 \cdot 10^{-7}$ in ppm
Air	2.72	-
Carbon monoxide	3.2	2100
Carbon dioxide	4.2	680
Sulphur dioxide	6.3	280
Hydrogen cyanide	4.0	780
Ammonia	3.5	1300
Propane	10.3	130
Butane	12.9	98
Octane	23.0	50
Benzene	15.8	77
Ethanol	8.1	190
Acetone	10.2	130
Ethyl acetate	13.0	97
Tetrachlorethylene	18.7	63
Freons F22	7.3	220
F12	10.3	130
F1281	12.0	110

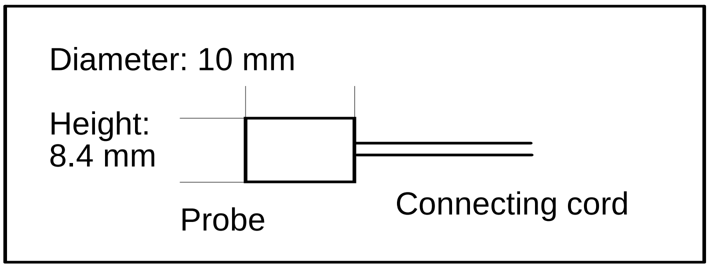
The values specified apply to an air temperature of 20 ℃ and an atmospheric pressure of 1013 hPa.

Surface Temperature Sensors

In practice, the limit of the uncertainty of measurement is not only determined by the uncertainty of refractive index measurement.

In order to avoid faulty measurements, it is also necessary to exactly know the temperature of the testpiece, or the temperature distribution throughout the measurement setup (thermal expansion coefficient of the materials!). Therefore, the AUK Environmental Sensor also has connection facilities for up to five material temperature sensors (surface temperature sensors). They precisely measure the temperatures on smooth, plane contact surfaces of technical components with a specific thermal conductivity of better than 10 $Wm^{-1}K^{-1}$·





The sensors are delivered in series with cable lengths of 5 m. Other lengths will be supplied on request. The sensors are hermetically sealed and will therefore withstand rough conditions in production environments.
The sensors are offers with screw-on, magnetic or adhesive holders for fixation to the testpiece.

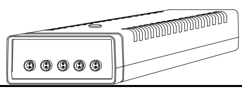
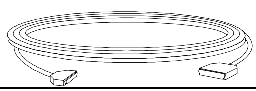
Dynamic behaviour

The dynamic behaviour depends on the specific conditions of the measurement. The time percentages specified are guideline figures only and refer to a testpiece of steel with a thermal conductivity of 50 $Wm^{1}K^{-1}$.

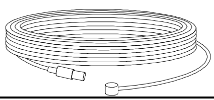
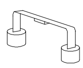
time percentages	T/50	T/90	T/95	T/98
(in sec)	3,2	7,8	12,4	30

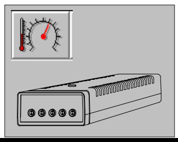
On request, the sensors can be supplied with a manufacturer's certificate or with a certificate of the German Calibration Service (DKD) or PTB. The measurement error specified does not include any user-specific error influences (thermal conductivity of the testpiece, heat transmission conditions at the point of contact between sensor and testpiece).

Scope of Equipment Supplied, Order Numbers

AUK Environmental Sensor 269302-5053.226	
AUK Connection cable 269302-5040.224	

Supplement to AUK: Material temperature sensor
(Material compensation)

Surface sensor 2 269300-3904.824	
Magnetic holder 2 269300-3900.524	



Technical specification

AUK Environmental Sensor

Measuring range

Air temperature	10 ℃...40 ℃
Atmospheric pressure	800 hPa...1200 hPa
Air humidity	10 %....90 % rel.humidity

Sensor reading cycle 1 s

Measurement uncertainty of individual components

Air temperature	100 mK
Atmospheric pressure	0.4 % of the measuring range
Air humidity	5.0 % rel.humidity

Measuring inaccuracy referred to the measuring distance 1.5 µm/m

Surface temperature sensor

Measuring range

Type OF 040050	-20 ℃...+ 40 ℃
Type OF 060050	0 ℃...+ 60 ℃

Sensor reading cycle 1 s

Measuring inaccuracy 100 mK

Literature

/1/ Edlen,B.: The Refractive Index of Air.
Metrologia 2 (1966), 71 - 80

Technical Specification of ZLM

Mean wavelength of He-Ne laser in vacuum	632.8nm
Wavelength stability	$8 \cdot 10^{-9}$ for 2 hours, $2 \cdot 10^{-8}$ for lifetime
Beam diameter	6mm
Max. output power of emerging expanded beam	1mW
Carrier frequency	640MHz / Intermediate frequency 2.56GHz
Number of measuring axes per laser ZLM 700 ZLM 800	 1 4 (further axes possible)
Resolution distance measurement Cube corner interferometer Plane mirror interferometer	 2.5nm 1.25nm
Measuring distance	≤40m, optionally till 120m
Angle measurement with angle interferometer Resolution Angular range	 $1.25 \cdot 10^{-7}$ rad ±8° till 20m distance
Angle meas. with straightness interferometer Resolution Angular range	 $3.3 \cdot 10^{-7}$ rad ±15° till 10m distance
Resolution straightness measurement 2m - Option 10m - Option	 29nm 145nm
Measuring range straightness measurement	±5mm
Measuring velocity	≤ 4m/s, optionally 12m/s translatory ≤ 320rad/s rotatory
Nonlinearly	±0.625nm (2.5nm resolution) ±0.312nm (1.25nm resolution)
Interfaces ZLM 700 / 800	32bit realtime counter signals (15ns) AQB counter input for e.g.. Heidenhain-scales (20 MHz) AQB counter output for Motion control (10 MHz) 16 x 12 bit ADC - input External Trigger in / Trigger out External to-zero fill
ZLM 800 Evaluation unit	19" – 3HE system for 1 till 4 axes cPCI – back plane for 8 slots CPCIC/PXI processor Pentium III 850 MHz
ZLM 800 Interfaces of Evaluation unit	for keyboard, mouse, monitor Ethernet, LAN, USB1/2, RS232, IEEE488 opt. External disk drive
Operating conditions	15°C till 30°C

Operating Conditions

The ZLM 700 / 800 is built for use both in rough industrial environments. The optical moduls are suitable for high vacuum. The measurement and reference signals are conducted via fibre-optic cables from the interferometer optics to the electronic signal processing unit, so that the signals cannot be disturbed by ambient electromagnetic influences.

For a safe operation of the device and the obtainment of fault-free measurement results have to be taken into account:

- The laser head needs a warm-up time of 10 - 15 minutes for wavelength stabilization

- LED of the laser measuring head

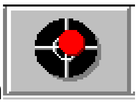
Red	**Laser is still unstable**
Green	**Laser is operating stably**

- the correct connection of the fibre optics cables

Mess	↔	**Mess**
Ref	↔	**Ref**

- Keep optical end surfaces of fibre-optic cables and the ghlass surfaces of the optical moduls clean!

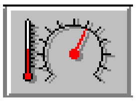
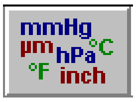
- The beam path must be well aligned with the mechanical measuring axis.

  Check position of optical axis via menu item 

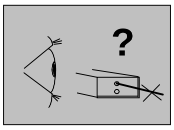
> **Important**
> **Covering: The same position of measuring- and reference beam in the quadrant field**
> (importantly for perfect interference signal)

- LED of AE 700
  AE 800 (1 LED per axis)

Red	**evalution of the light signals NOT possible**
Green	**Interference signal sufficing**

- enter the correct environmental data via menu items  and 

- no interruption of the beam path during the measuring operation



Troubleshooting

1. Laser measuring head

errors	causes	action
Laser doesn't ignite	- fuse defect - power supply defect - high voltage defect - aging laser tube - wrong line voltage	- inform customer service - inform customer service - inform customer service - inform customer service - right line voltage
LED remains permanently "red"	- Regulation altered or faulty - Location laser measuring head too warm - Feedback *	- inform customer service - keep temperature ≦30℃ - new adjusting of measuring set-up
LED switches to "red" or flashes during the operation	- Laser control altered or faulty - Location laser measuring head too warm - Feedback *	- inform customer service - keep temperature ≦30℃ - new adjusting of measuring set-up
No light at electrical socked „Reference“ (reference = upper electrical socked)	- inner defect in the laser measuring head	- inform customer service
No light at electrcal socked „Mess“ (measuring = beneath electrical socked)	- beam path not correctly adjusted - inner defect in the laser measuring head	- new adjusting of measuring set-up - inform customer service
At the measuring head cable no light at the reference egress	- Measuring head cable defect, if light is available at electrical socked (rerence egress = upper electrical socked)	- Exchanging measuring head cable
At measuring head cable is no light at measuring egress	- Measuring head cable defect, if light is available at electrical socked (measuring egress = below electrical socked)	- Exchanging measuring head cables

***** *Feedback*

If a part of the light is reflected back into himself, it comes to the feedback. Through this the regulation fails. This is the case at particularly exact adjustment at plane mirror interferometers (also Straightness and Squareness measurement). Normally the reflective planes are minimally tilted because of the tolerances of the components. At feedback then she it prevent through a lowly disgruntle the adjustment.

2. Evaluation unit AE 700

AE 700 N **Dockingstation with PCI-BUS - system and notebook**
AE 700 PCI **Industrial PC with PCI-BUS - system**
AE 700 cPCI-PXI **Industrial PC with cPCI/PXI-BUS - system**

errors	causes	action
Control lamp to connection side under "Stat" doesn't glow	- Evaluate unit no right connected - evaluate unit defect	Checking all connection, inform customer service
Control lamp connection front under „Stat“ illuminate „red“ despite connected fibre optics cable	- no Light at measuring head cable output „Ref“ or „Mess“ - insufficiently congruenc between measuring and reference beam - evaluate unit defect	See table “laser measuring head” adjustment the congruence improve inform customer service
Control-LED connection front is flaring during function	- Measuring head cable connection insufficiently - measuring head cable defect - insufficiently congruence between measuring and reference beam - evaluate unit defect	Inspect Measuring head cable, measuring head cable exchang improving adjustment of congruence inform customer service

Care and Maintenance

- The ZLM 700 / 800 does not need any periodic maintenance operations.
- All bright steel parts are made of high-grade non-magnetic steel. The optical surfaces of the interferometers must be kept clean. Coarse faultings impair the measurement result.
- On optical surfaces no touch with the fingers. Dust should be removed only with a clean brush. For removing coarse dirt, use a wad of cotton wetly with distilled water. For removing greasy dirt, use a wad of cotton wetly with cleanse spirits.
  In order to avoid such soiling, always cover up unused optical components, or keep them in the carrying case.
- There are no fuses to be changed by the user. Inform the JENAer Meßtechnik GmbH service department in case of laser failure. The fuses of the laser head are inaccessible to the user and can only be changed by authorized service staff. Evalution unit AE 700 and the AUK Environmental Sensor do not have any fuses. If they fail, call the JENAer Meßtechnik GmbH service department.
- It is recommendable to have it checked all 2 years and, if necessary, calibrated by the manufacturer.

IMPORTANT

<u>Do not open:</u> **Laser mesasurement head and AE 700 / AE 800 !**
The right to claim under guarantee goes out when opening the device unauthorizedly.

Service

The specialists off JENAer Meßtechnik GmbH stand on hand by all occur asks and problems to work with ZLM 700/800

Service Address:

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D-07745 Jena
Germany

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