C Interferometer with cube corner reflectors for the angle measuring

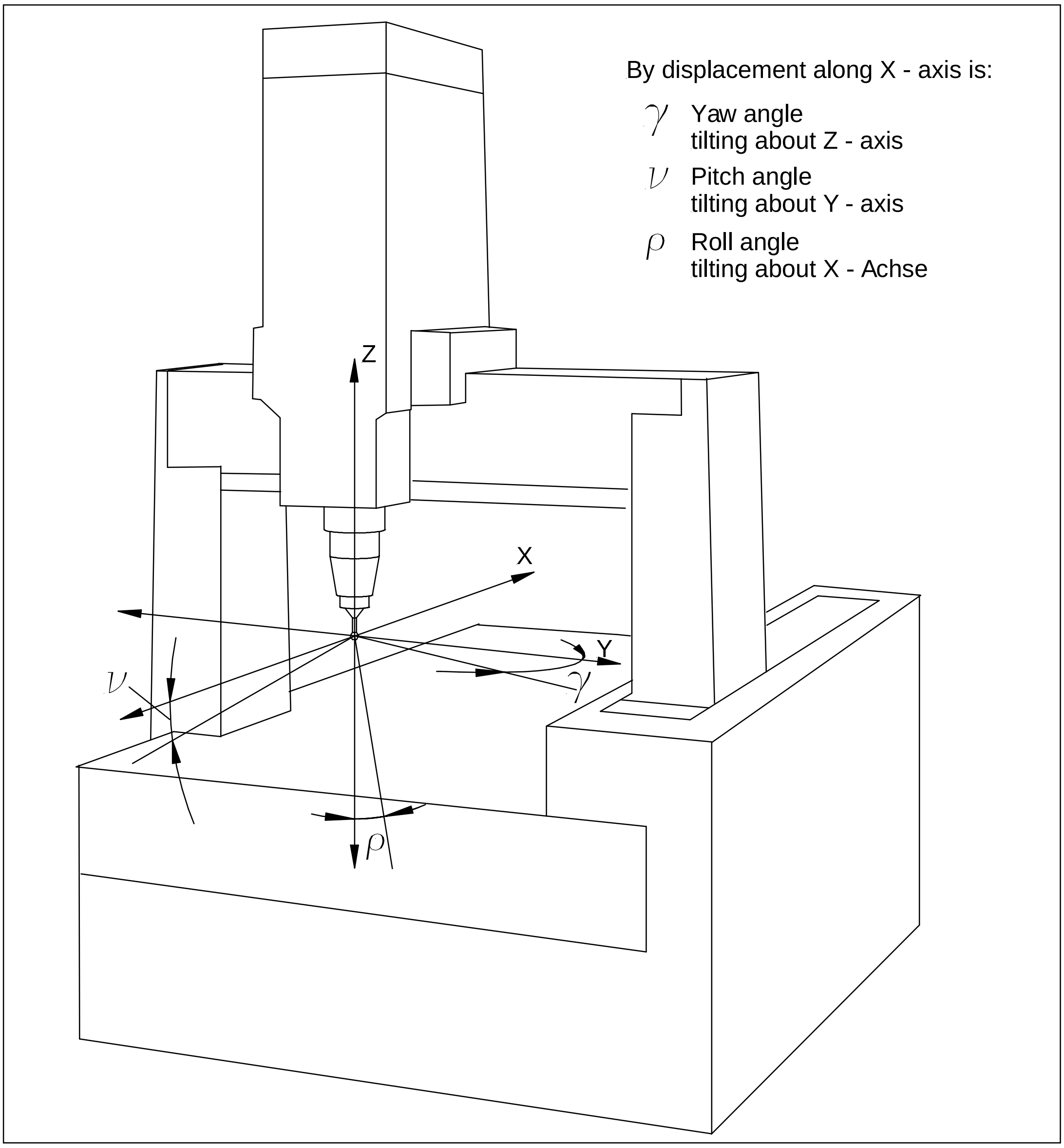


Fig. 1: Tilt angle at a coordinate measuring machine

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.

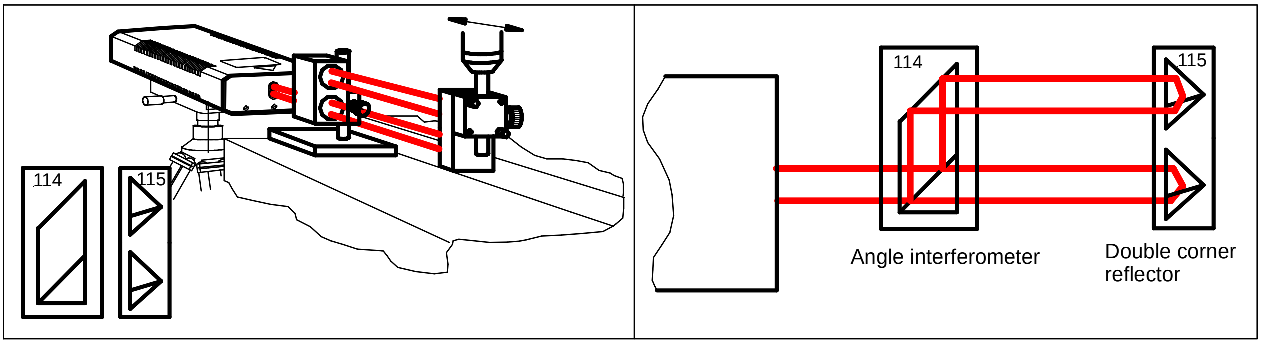


Fig. 2: Optical arrangement: angle interferometer for the pitch angle measuring
(for the yaw angle measuring: turn angle interferometer and double corner reflector by 90°)

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

Angle interferometer with standard optical modules:

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

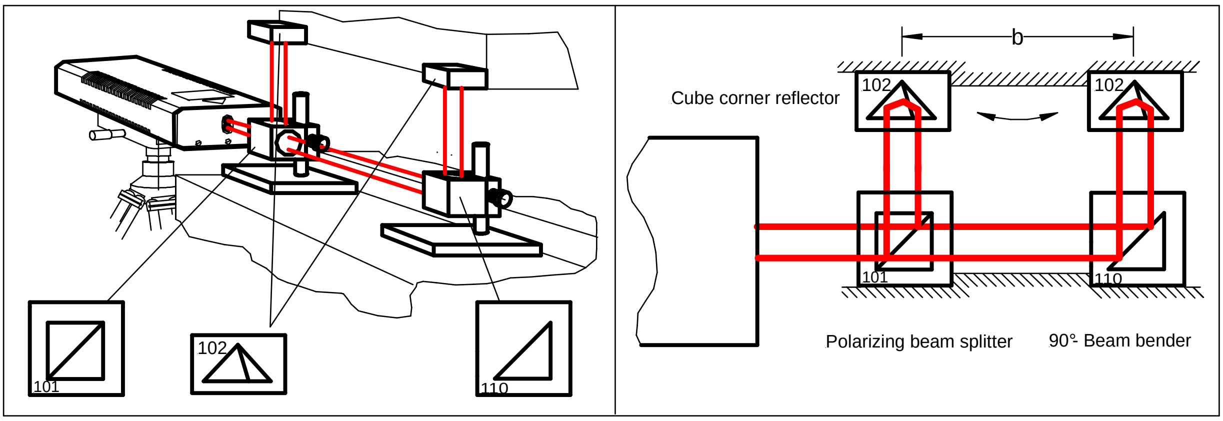


Fig. 3: Optical arrangement: angle interferometer with the standard optics modules

Angle interferometer with straightness optical modules:

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.

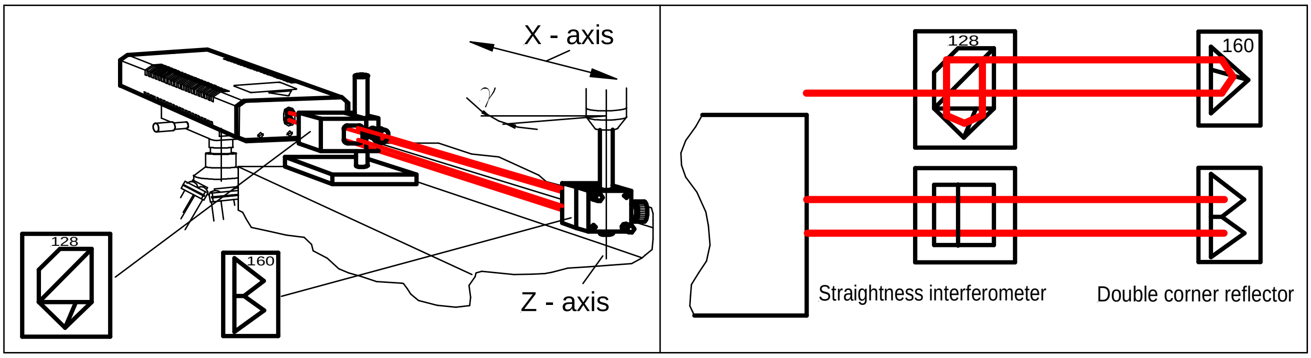


Fig. 4: Optical arrangement: angle interferometer (Straightness interferometer 128 with cube corner reflector 160) for the yaw angle measuring
(for the pitch angle measuring: turn angle interferometer and double corner reflector by 90°)

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).

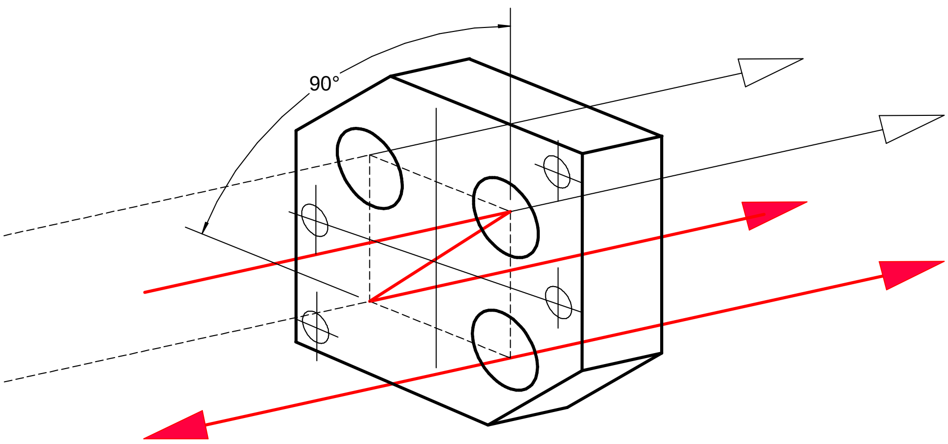


Fig .5: Function of the Beam offset prism 120

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).

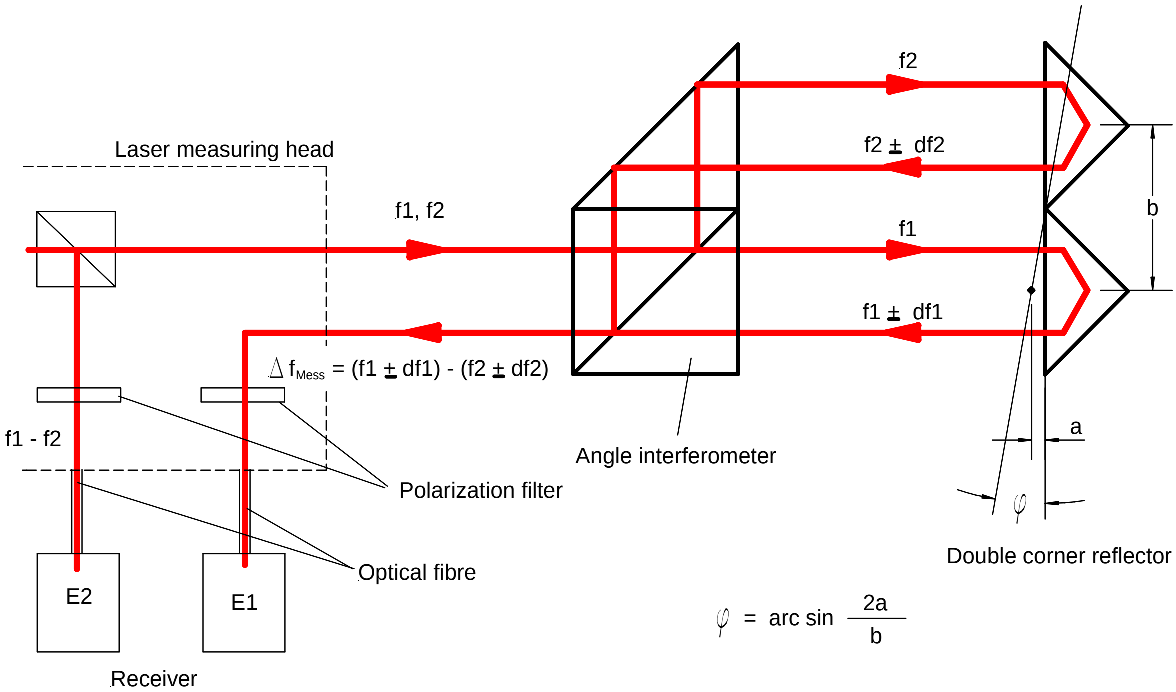


Fig. 6: Function scheme of angle interferometer

Assembly

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

Angle interferometer ($1.25 \cdot 10^{-7}$ rad resolution)

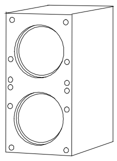
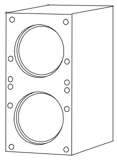
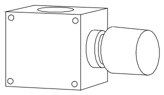
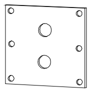
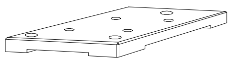
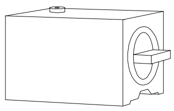
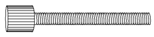
Angle interferometer 114 269302-4015.324		Quantity: 1
Double corner reflector 115 269302-4015.424		Quantity: 1
Clamping fixture 507 269302-4010.325		Quantity: 2
Beam stop plate 516 269302-4014.210		Quantity: 2
Mounting plate 504 269302-4014.410		Quantity: 2
Magnetic base 506 260298-3000.128		Quantity: 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)

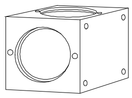
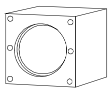
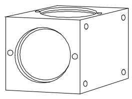
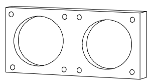
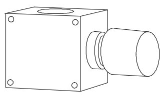
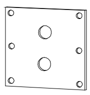
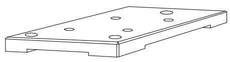
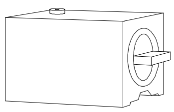
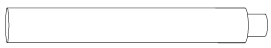
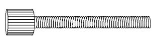
Polarizing beam splitter 101 269302-4010.124		Quantity: 1
Corner reflector 102 269302-4010.224		Quantity: 2
90° beam bender 110 **269302-4011.024**		Quantity: 1
Coupling plate 510 **269302-4014.510**		Quantity: 1
Clamping fixture 507 269302-4010.325		Quantity: 2
Beam stop plate 516 269302-4014.210		Quantity: 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)

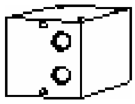
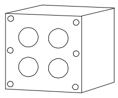
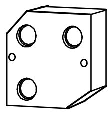
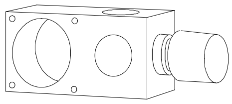
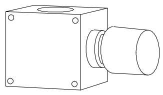
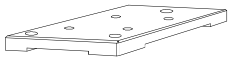
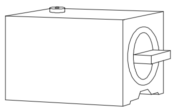
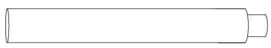
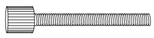
Differential interferometer 128 2693 02- 4012.824		Quantity: 1
Double corner reflector 160 269302- 4016.524		Quantity: 1
Beam offset prism 269302-4008.424		Quantity: 1
Clamping fixture 508 269302-4010.125		Quantity: 2
Clamping fixture 507 269302-4010.325		Quantity: 1
Mounting plate 504 269302-4014.410		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

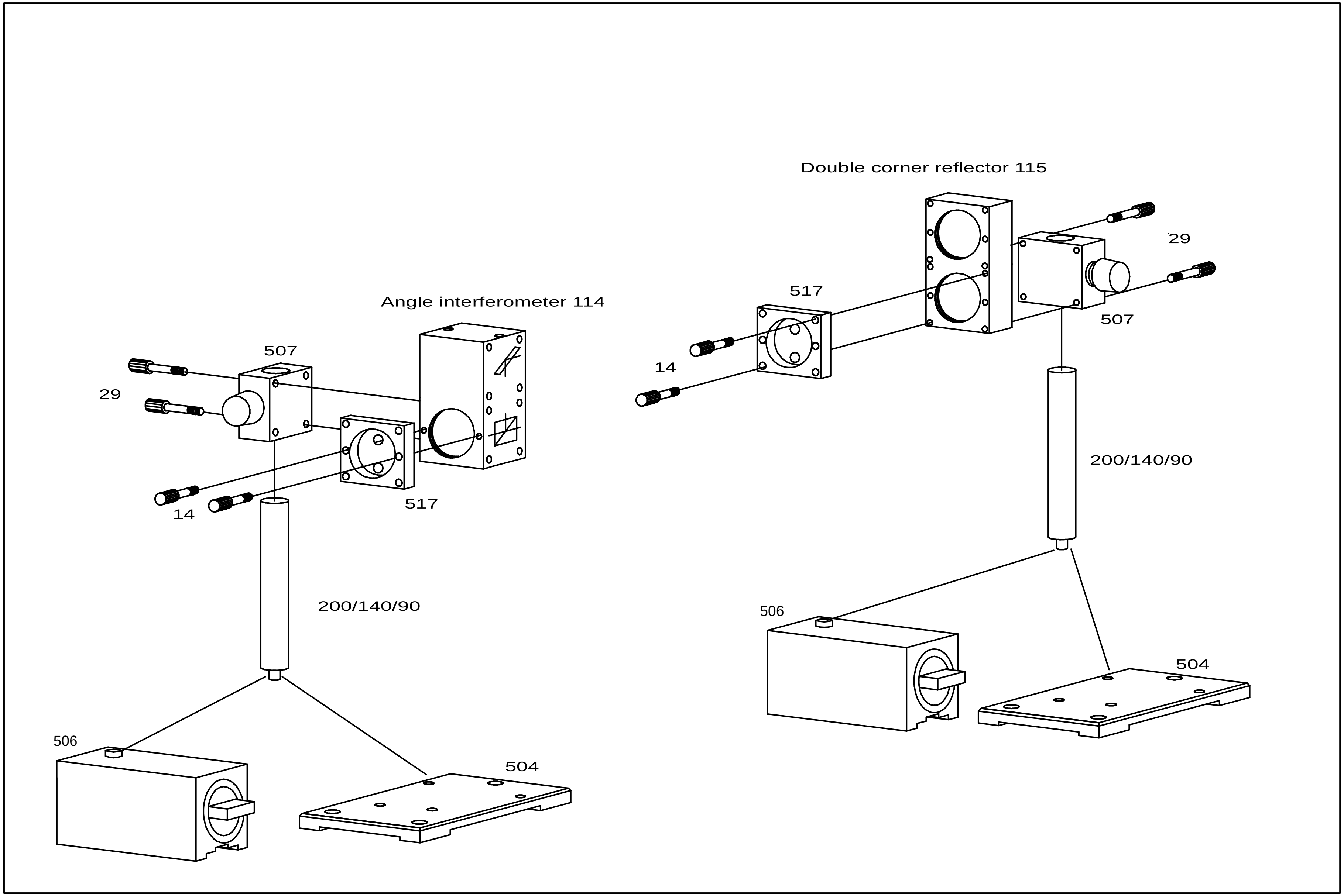


Fig. 8: Assembly of optical components

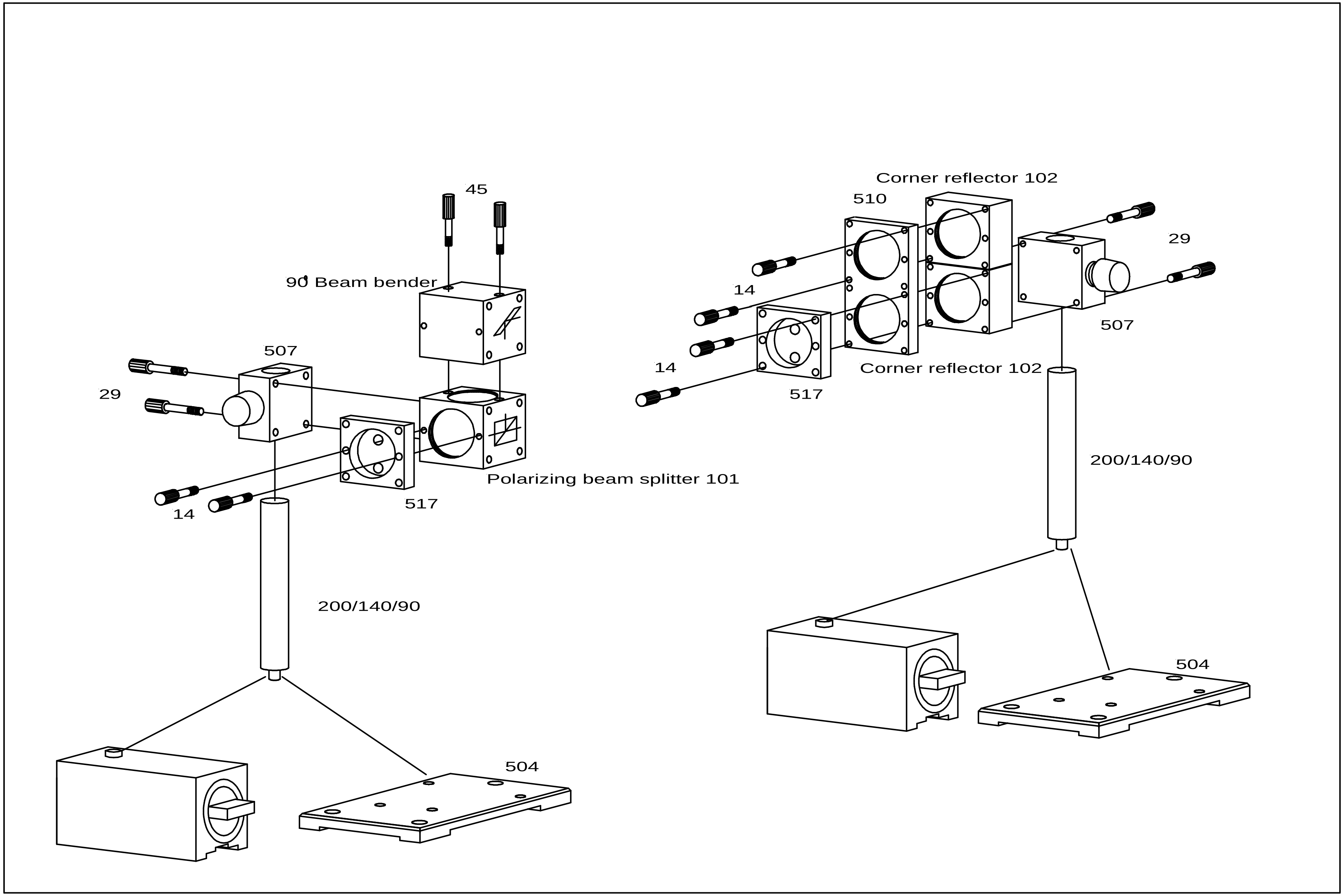


Fig. 9: Assembly of optical components

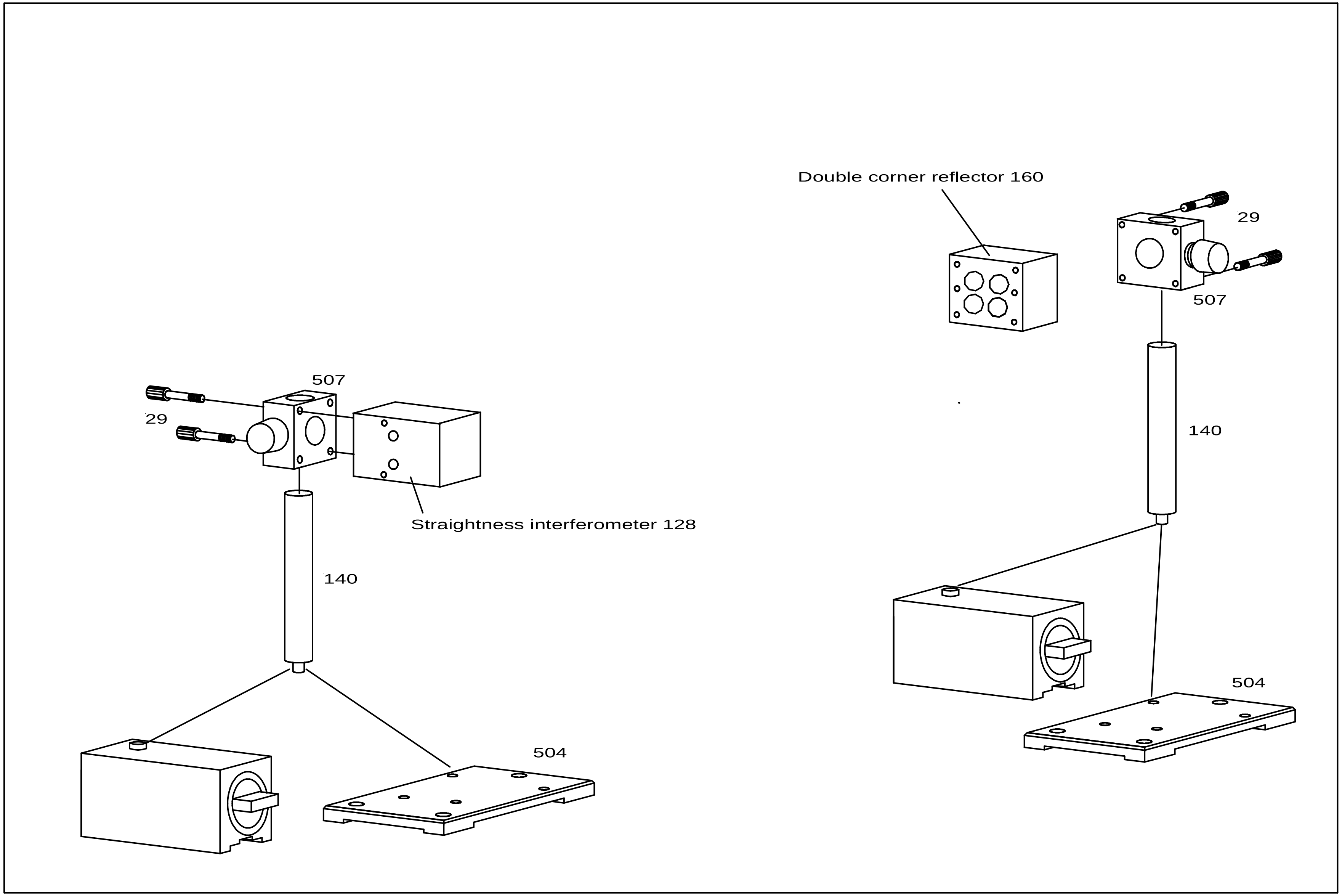


Fig.10a: Angle measurement with Straightness interferometer 128 - horizontal configuration

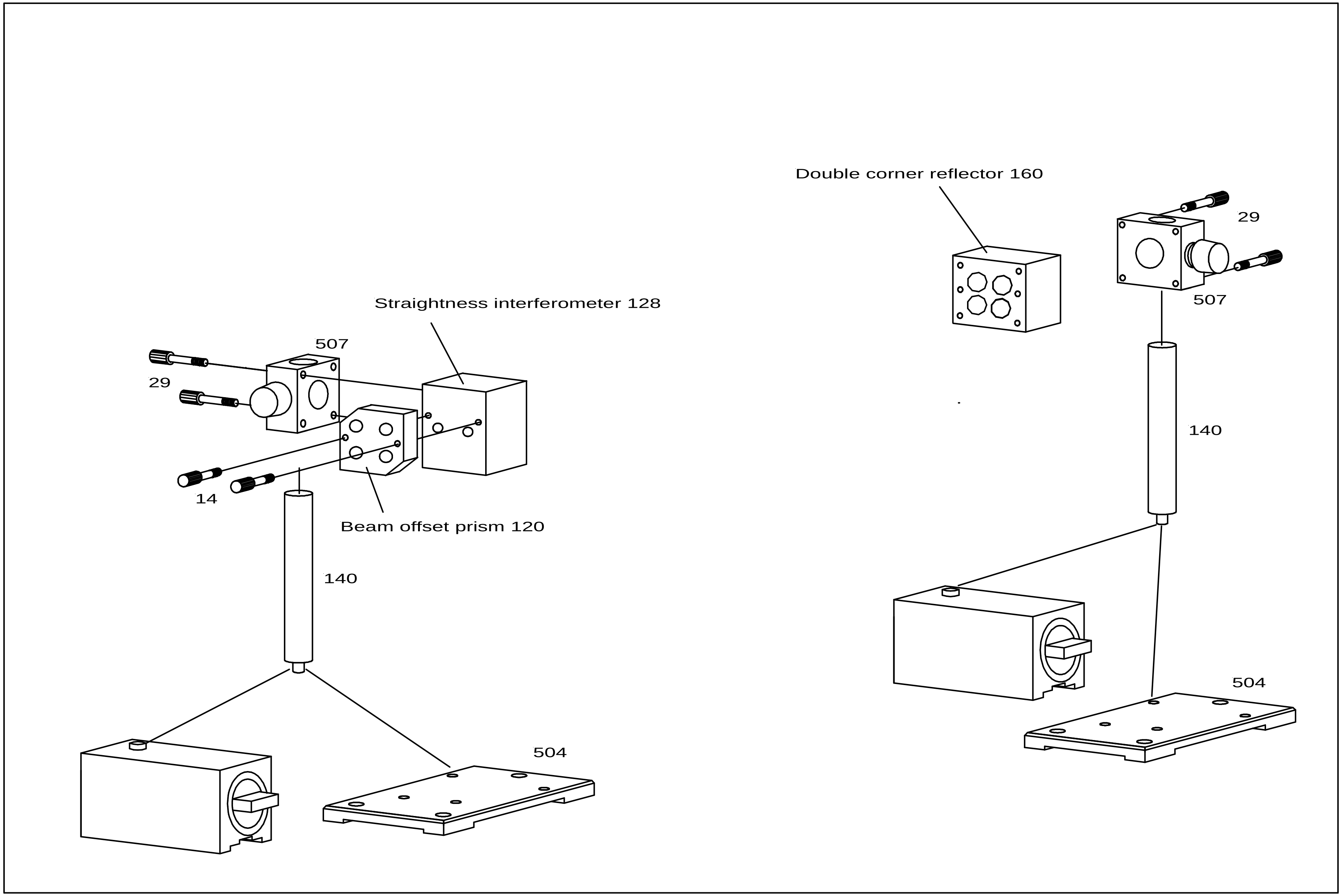


Fig.10b: Angle measurement with Straightness interferometer 128 - vertical configuration

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.

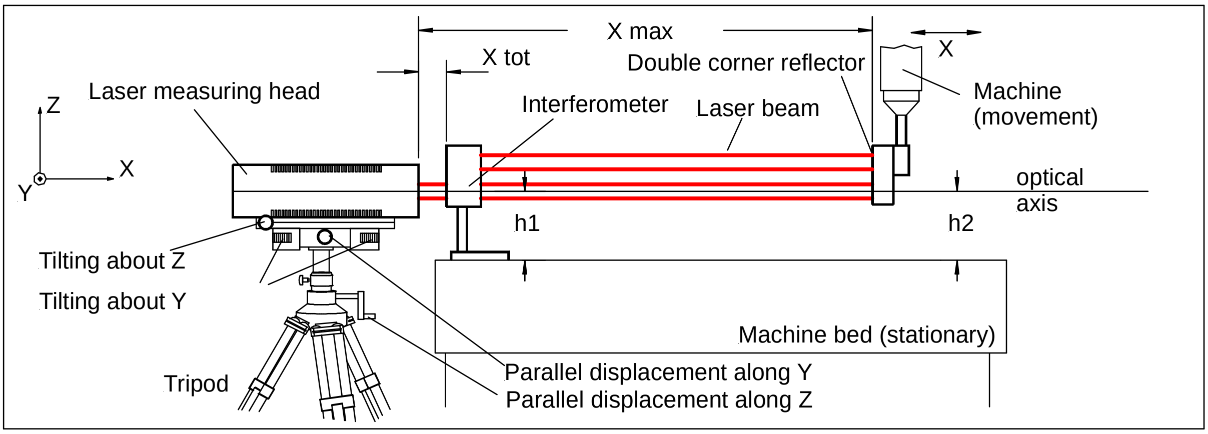


Fig. 11: Measuring setup, optical path

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).

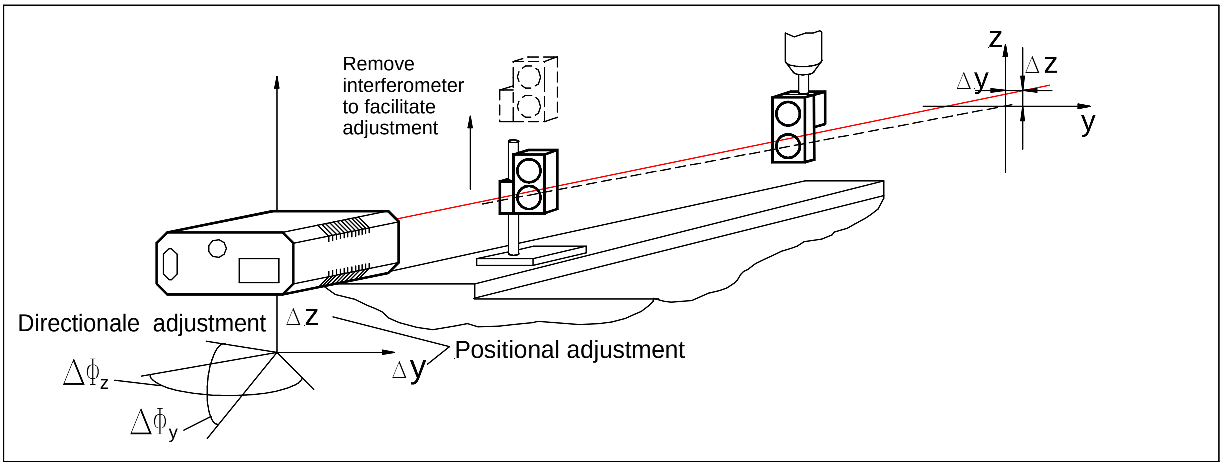


Fig. 12: Alignment of the beam path

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

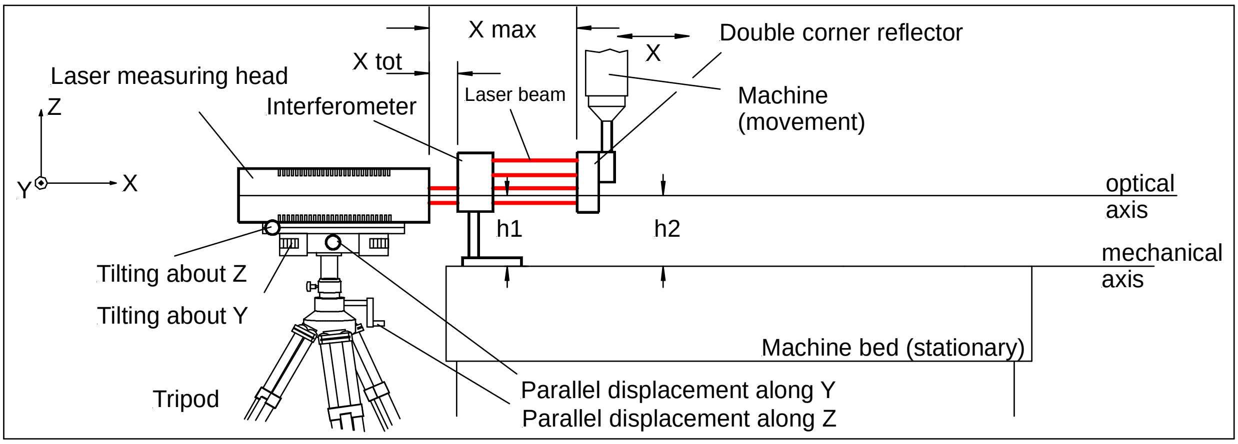


Fig. 13: Positional alignment of the beam path

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

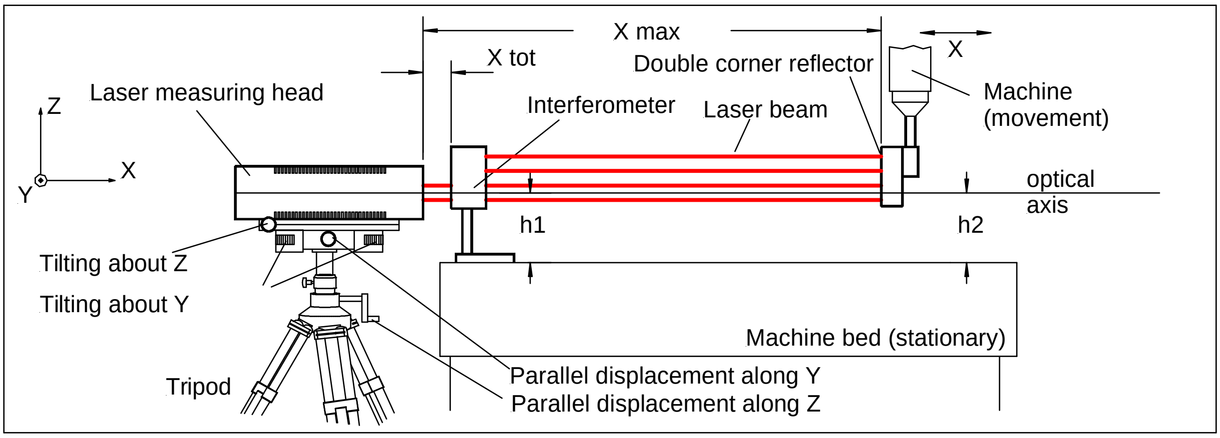
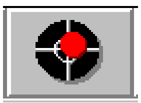


Fig. 14: Directional alignment of the beam path

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:

   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 .

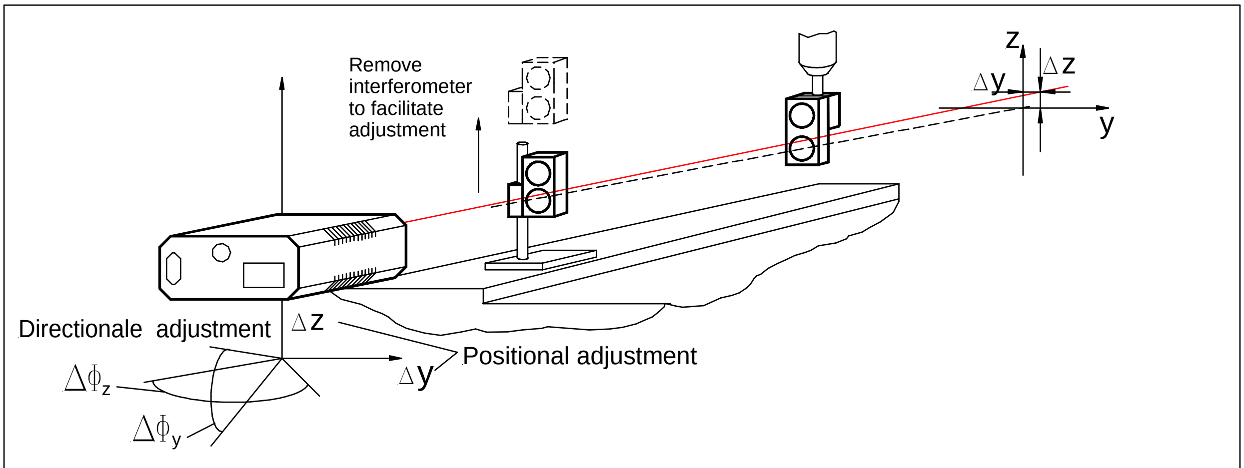


Fig. 15: Aligning the angle interferometer

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).