

## Flatness measurement

### 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:

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

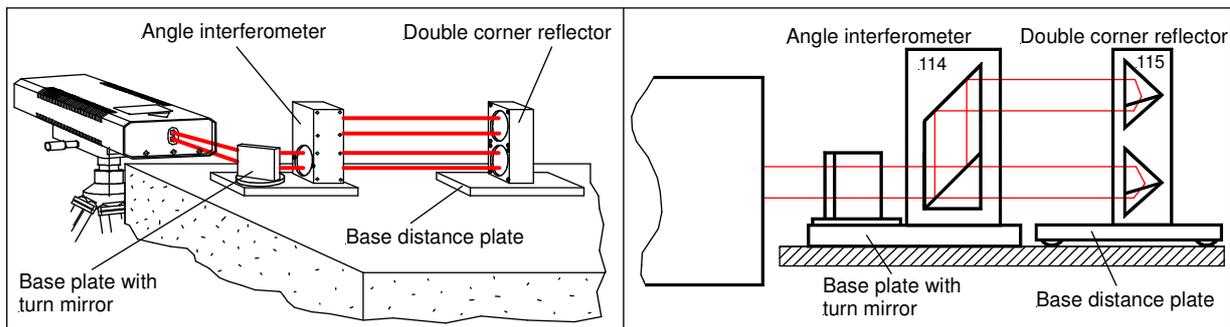


Fig. 1: Flatness interferometer (optical arrangement)

## Functional description

### Flatness interferometer

The flatness interferometer base functional principle of angle interferometer.

The two light modes emerging from the laser head are separated 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  $f_1$ , while the reference reflector only receives light of frequency  $f_2$ .

With the corner reflector unit at rest, E1 detects the laser's differential frequency ( $f_1 - f_2 = 640\text{MHz}$ ), 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  $\pm df_1$  and  $\pm df_2$ , respectively. Accordingly, detector E1 registers a measuring frequency of  $\Delta f_{\text{Meas}} = (f_1 \pm df_1) - (f_2 \pm df_2)$ , 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 obtained is the frequency shift  $\Delta f_{\text{Meas}}$  due to the Doppler effect; this shift is a measure of the displacement  $\Delta x$  of the Double corner reflector (Fig. 2).

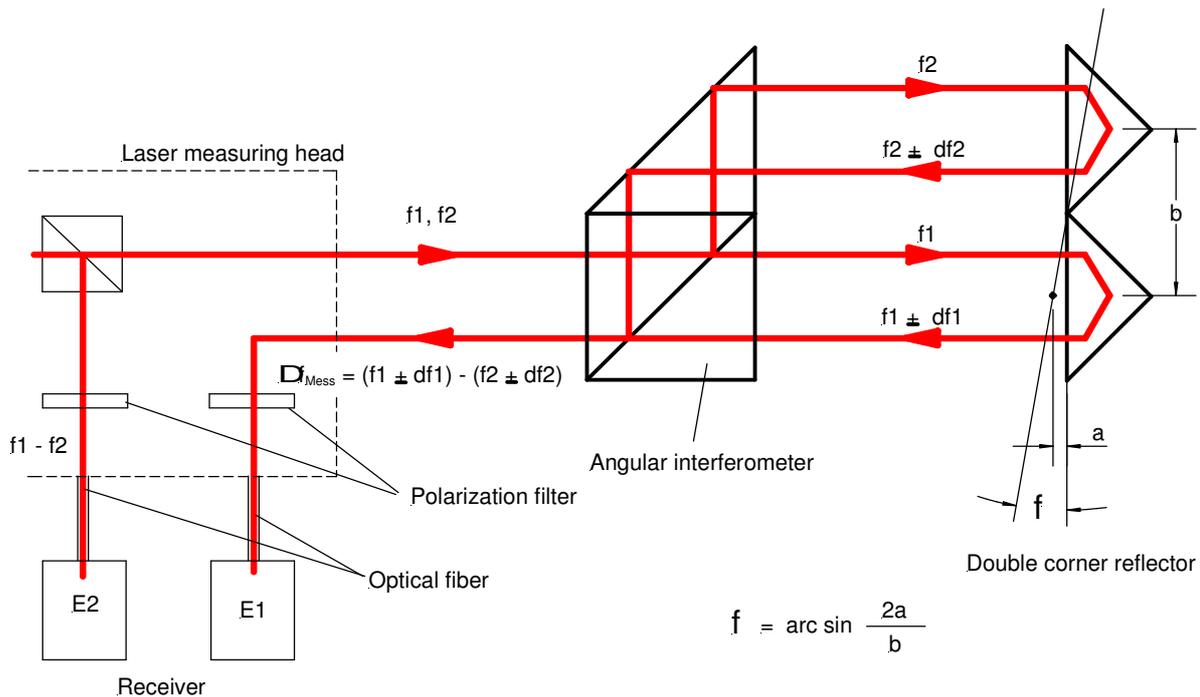
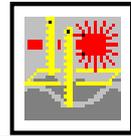


Fig. 2: Angle interferometer

**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.

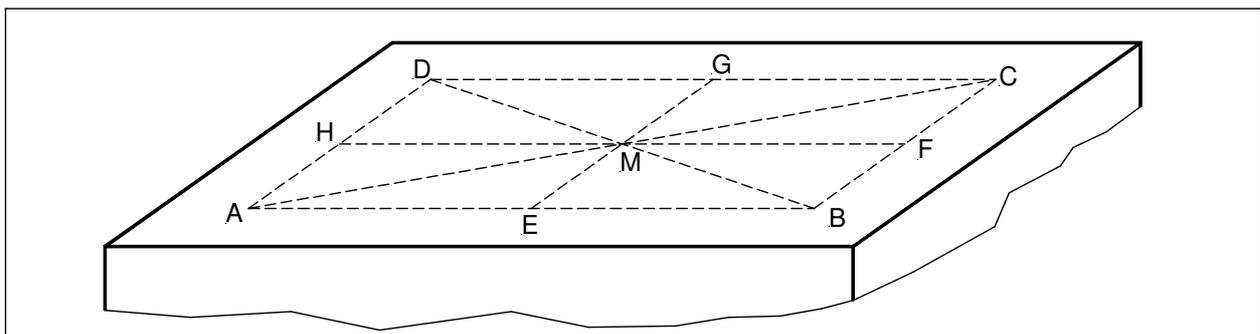


Fig. 3: Measuring grid „Union Jack“

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!).

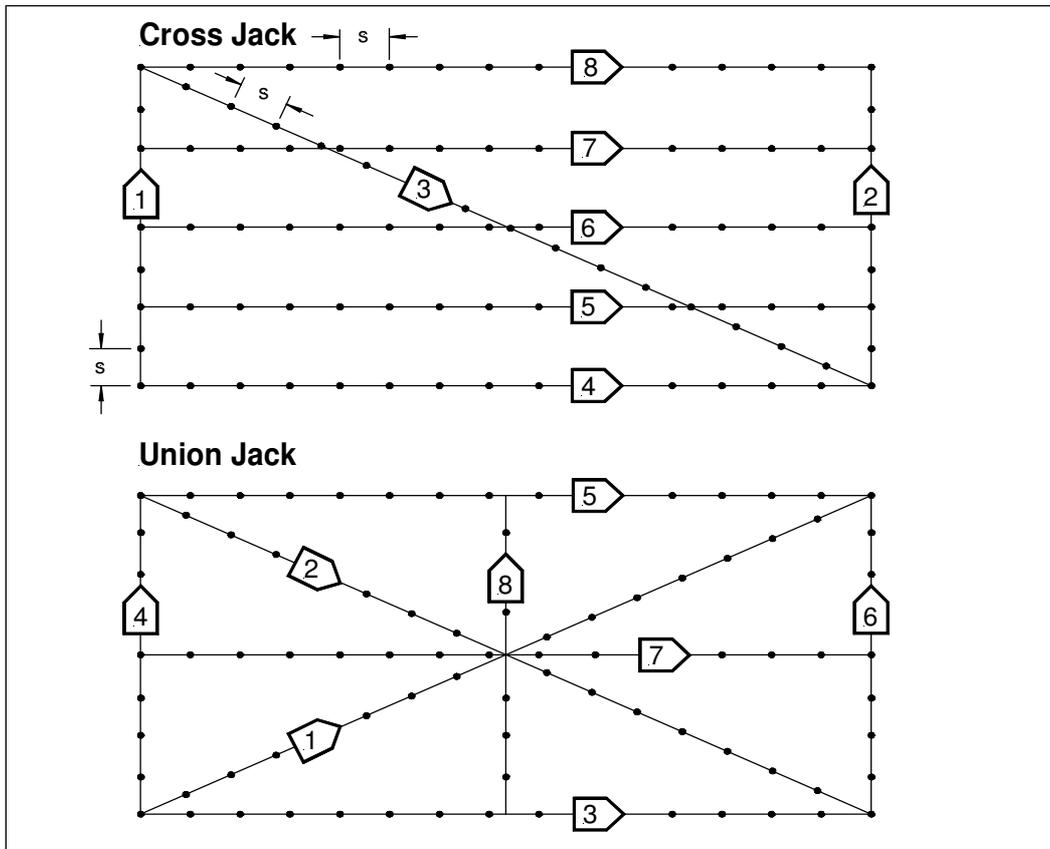
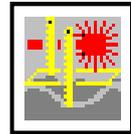


Fig. 4: Plan of the measuring grids

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

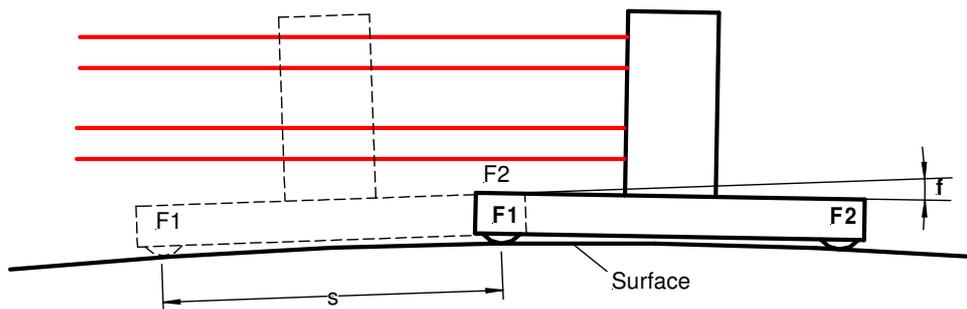


Fig. 5: Displacement of the double corner reflector with a base distance plate

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).

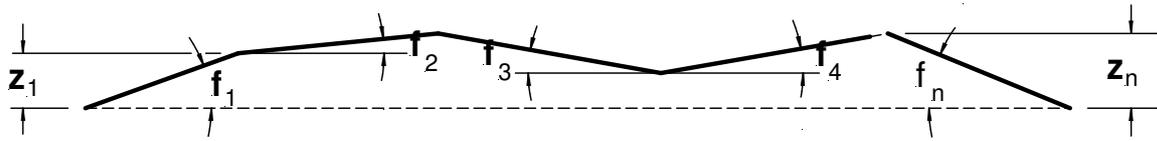
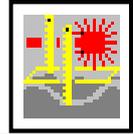


Fig. 6: Determination of the height (straightness) profile of a line

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  $\delta a$ ) and corrected to a reference line.

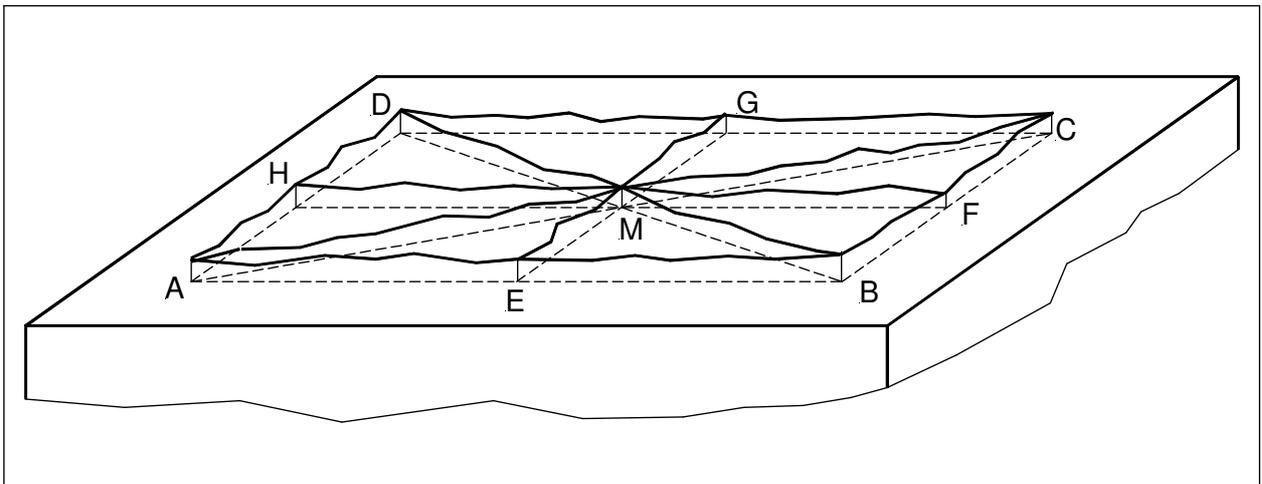


Fig. 7: Flatness of the total plane

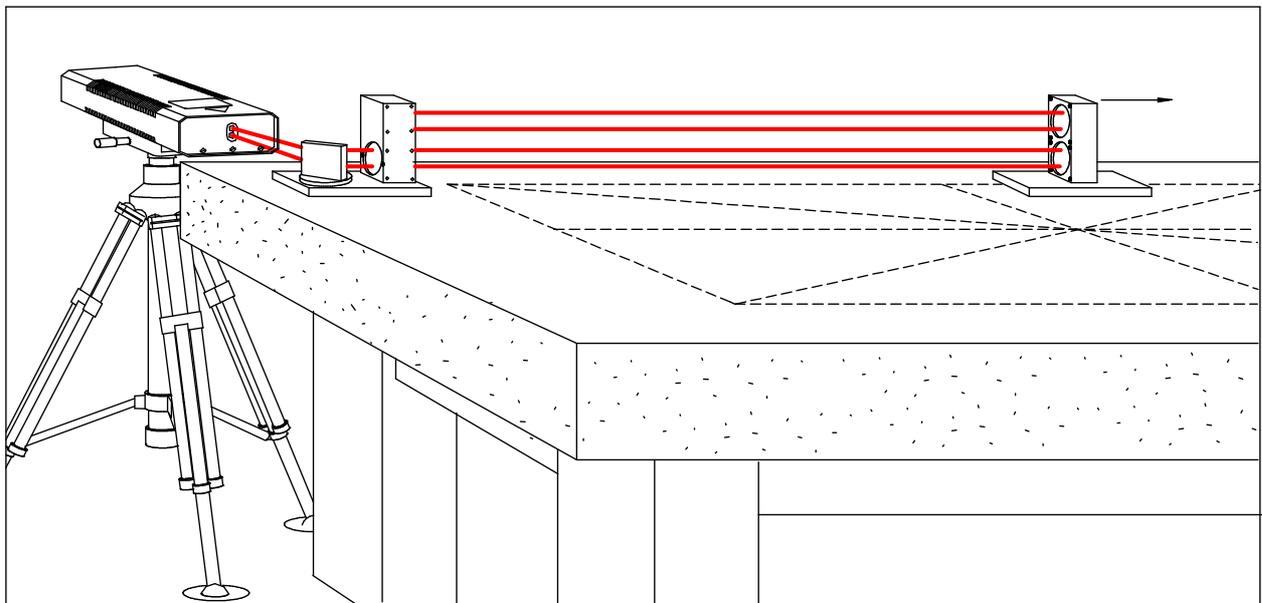
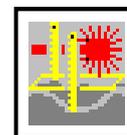


Fig. 8: Measuring setup at a surface plate



## Flatness measurement

### Assembly

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

### Flatness interferometer

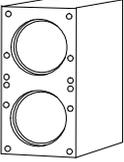
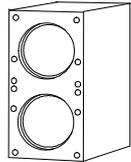
<b>Base plate with turn mirror 118</b> 269302-4015.524		Quantity: 2
<b>Base distance plate 150</b> 269302-4011.625		Quantity: 1
<b>Base distance plate 100</b> 269302-4011.725		Quantity: 1
<b>Base distance plate 50</b> 269302-4011.825		Quantity: 1
<b>Angle interferometer 114</b> 269302-4015.324		Quantity: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

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

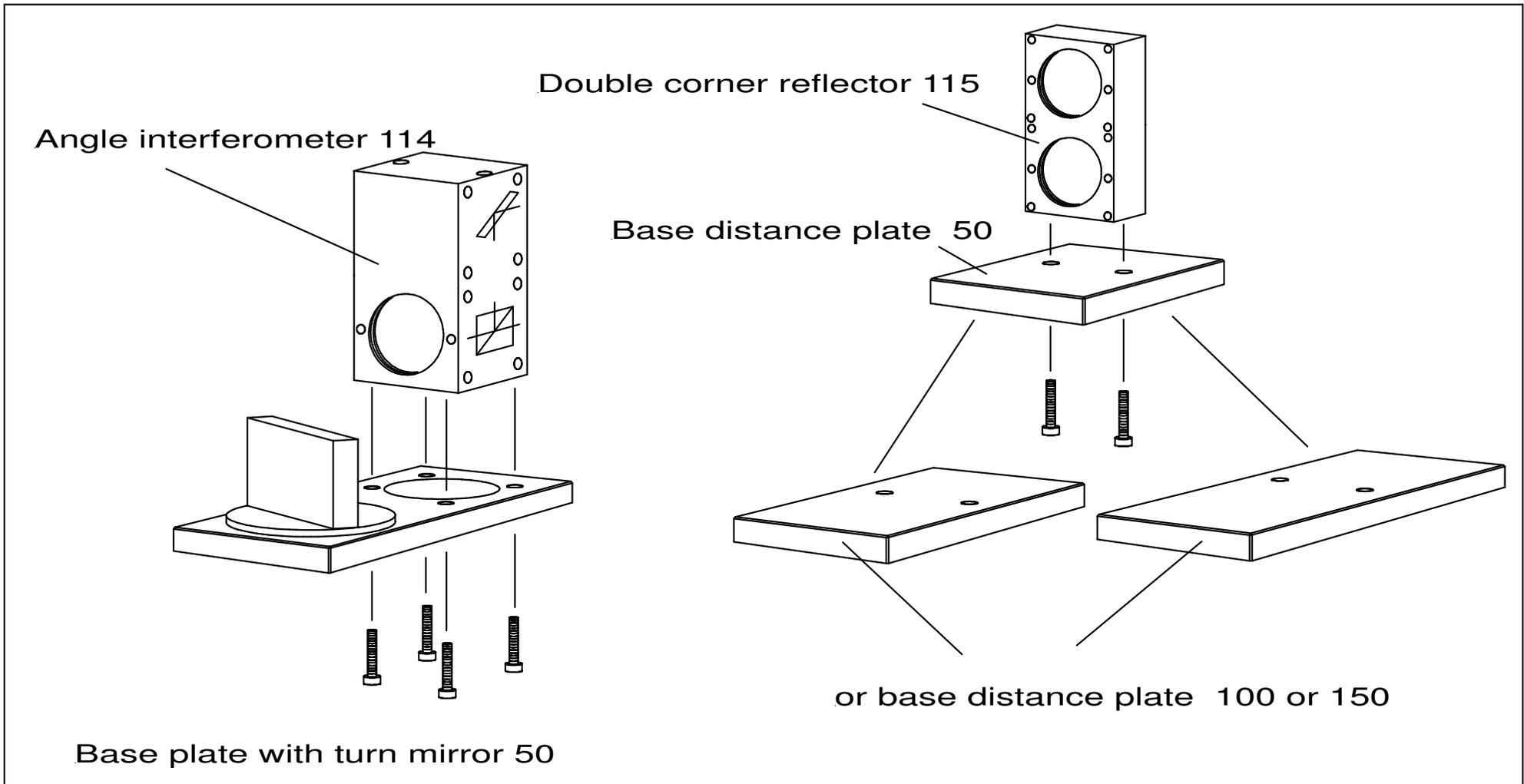
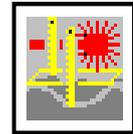


Fig. 10: Mounting assembly flatness measurement



## 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 ( $h_1 = h_2$  in Fig. 11) in order to avoid angular errors.

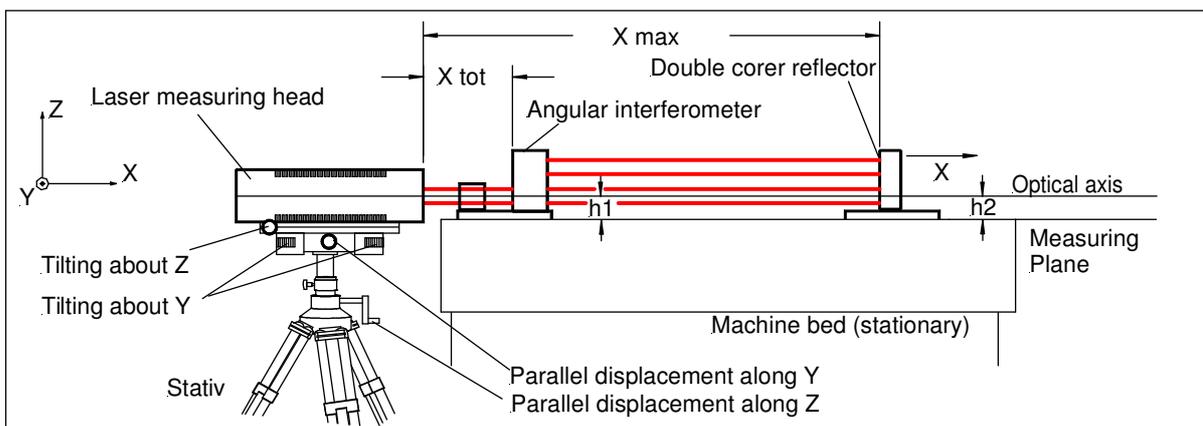
4. Roughly align the laser beam with the optical axis of the installed optical modules.

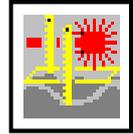


#### Tips:

- (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.  $\Rightarrow$  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



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 (parallel displacement along y and z) ( $\Delta y, \Delta z$ )
- directional alignment (angle tilting about y and z) ( $\Delta\phi_y, \Delta\phi_z$ )

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).

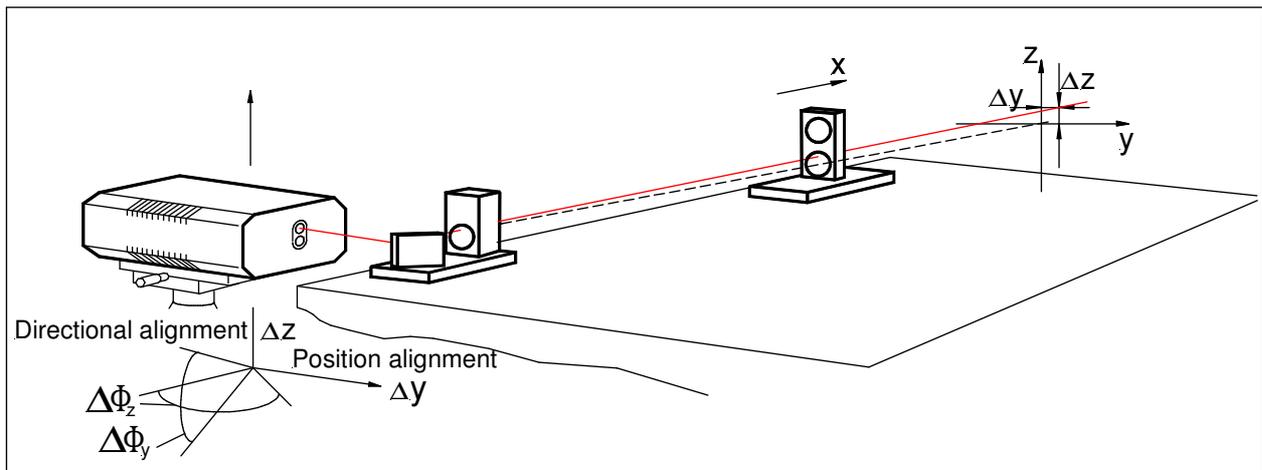


Fig. 12: Alignment of the beam path

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

- |  |   |   |
|--|---|---|
| Positional alignment,<br>Parallel displacement | ⇒ | at the Double cube corner reflector position nearest to the laser, Fig. 13    |
| Directional alignment,<br>tilting position     | ⇒ | at the Double cube corner reflector most distant from the laser head, Fig. 14 |

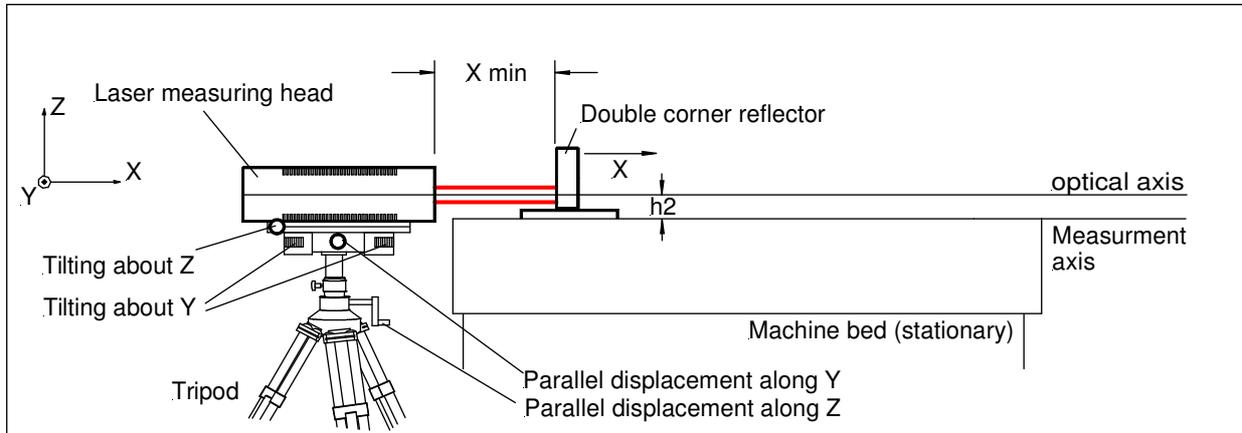
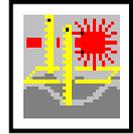


Fig. 13: Positional alignment

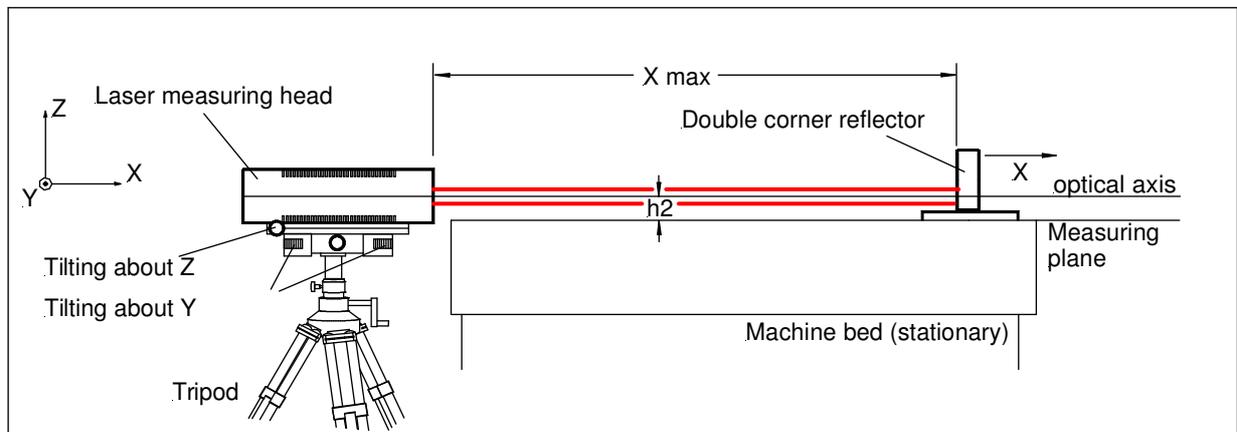


Fig. 14: Directional alignment

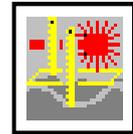
## Adjustment

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.



## Flatness measurement

- 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:

$\Delta y$  - Turn the micrometer screw of the adjustable table to displace the laser in parallel.

$\Delta z$  - 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).