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# *Applications*

D

## D. Measurement applications

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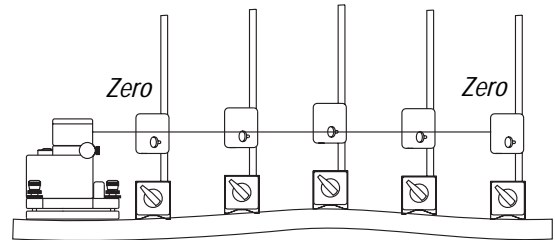
# STRAIGHTNESS

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**Fundamental straightness measurement** where the measurement value from the detector is read, for example, in the *Values* program.

## With two zero points as reference.

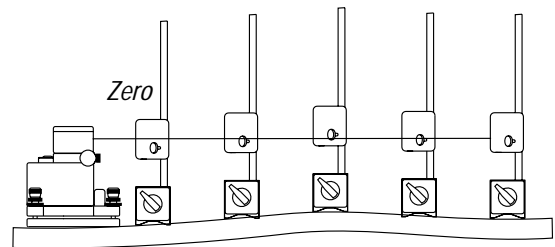
The laser beam is adjusted to pass through two selected reference points at the same distance from the measurement object. The measurement value is set to zero at the reference points. The measurement value at the other points will show the deviation from the straight line between the reference points.



*(One detector in five different positions.)*

## With the horizontal plane as reference.

The laser beam is levelled according to the vials on the transmitter and the value on the first point is zeroed. The measurement values on the other points will show the deviation from the horizontal plane.

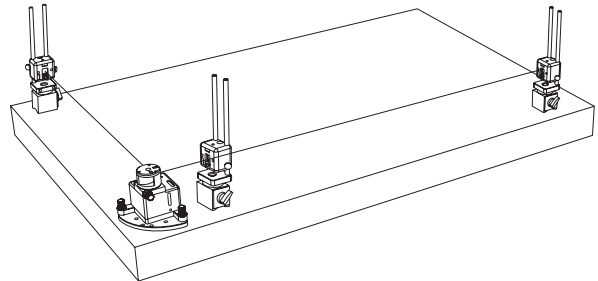


**Fundamental flatness measurement.** The same principle as for straightness measurement, but one dimension is added. Suitable program is *Values*.

**With one reference plane that “rests” on three ref.points.**

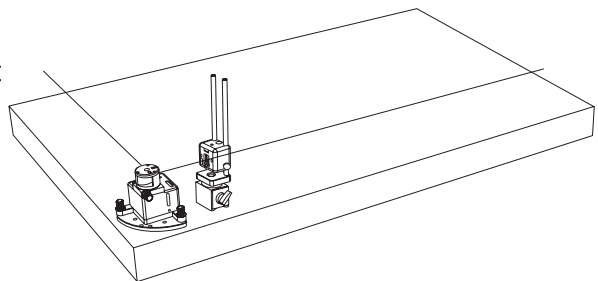
The laser beam is adjusted to pass through 3 selected ref.points at the same distance from the measurement object. The measurement values at the reference points are levelled to zero. The measurement values at the other points will show the deviation from the laser plane.

*(One detector in three different positions.)*

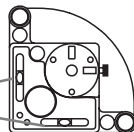


**With a reference plane parallel to the horizontal plane.**

The laser beam is levelled according to the vials and the measurement value at the first point is set to zero. The measurement values at the other points will show the deviation from the horizontal plane.



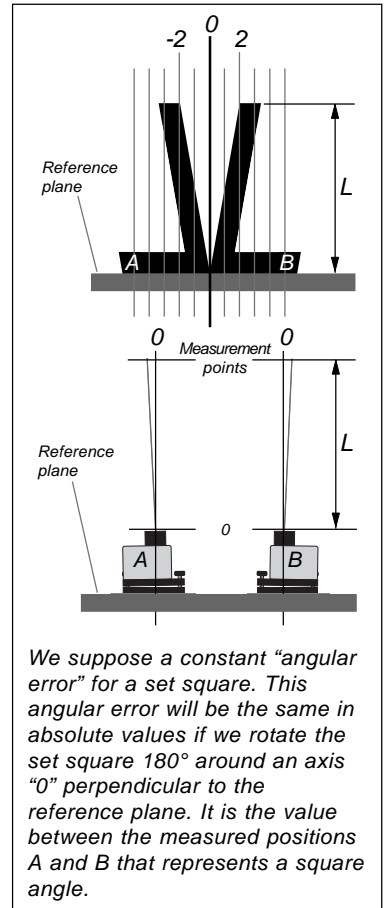
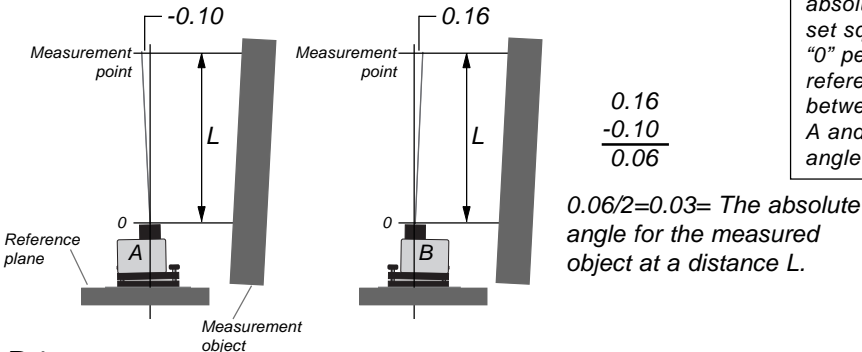
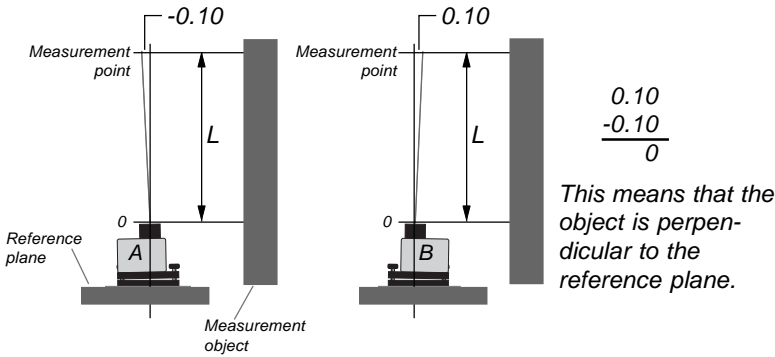
*Level according to vials.*



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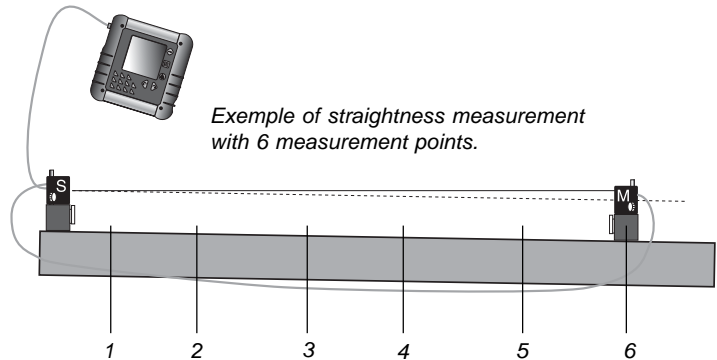
# SQUARENESS MEASUREMENT WITH INDEXING

When a very high accuracy is wanted when measuring squareness, where we need to get an even higher accuracy than for the laser transmitter (D22 according to technical specifications 0.01 mm/m), we use a method where the laser transmitter is indexed 180°. The picture to the right shows the principle. The method is suitable for measurement of straightness compared to two points on a reference plane, or for measuring plumb where we use the vials on the laser transmitter as reference.



# STRAIGHTNESS MEASUREMENT WITH S- AND M-UNIT

You can perform a straightness measurement with the S- and M-unit (i.e. no separate laser transmitter is used). The S-unit is used as reference transmitter and the M-unit as detector. Follow the instructions below.



1. Mount the S- and M-unit on magnet bases.
2. Adjust the laser beam from the S-unit visually to hit detector centre on the M-unit, placed on the measurement position furthest away. (The beam from the M-unit is not used.) Then the beam will be parallel to the measurement object.
3. Decide the number of measurement points and the distance between them.
4. Start the Straightness program and follow the instructions on the display.
5. Move the M-unit to the measurement points and register the values according to instructions on the display.
6. After the last measurement point, choose zero points in the program. Read the values and decide the straightness of the measured object. If you wish, make a printout of the graph and table on the display.

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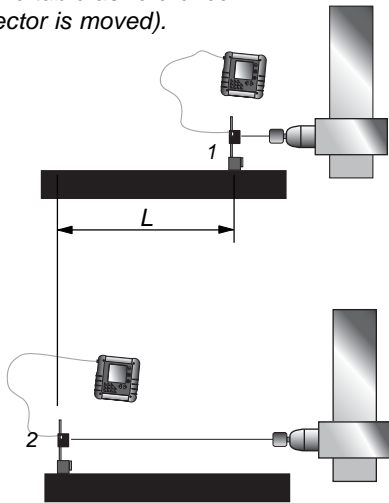
# POINTING DIRECTION

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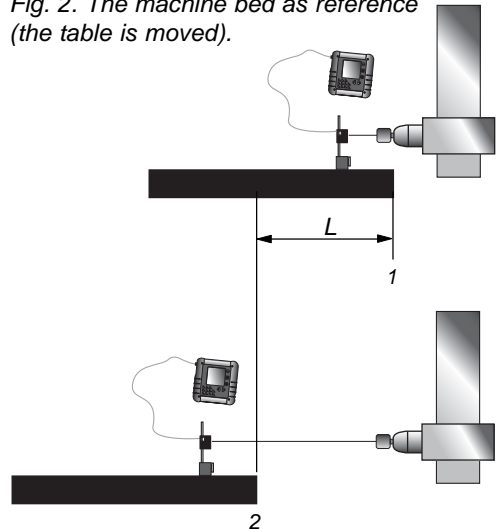
**Measuring pointing direction** in an arbor or milling machine can be done with the table as reference or the movement of the table as reference. By doing this we are able to see if the table is parallel to the machine bed.

The measurement in Fig. 1 shows the pointing direction of the spindle relative to two points at the table. When measuring the pointing direction of the spindle relative to the machine bed/movement (Fig. 2), let us say we get a different measurement value. The difference between these two values is the deviation from parallelity for the table and the movement.

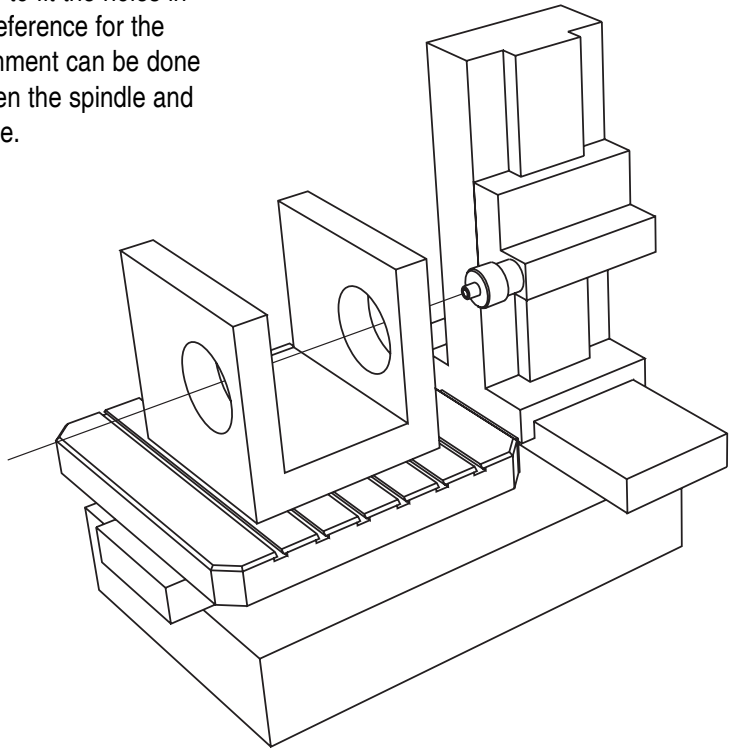
*Fig. 1. The table as reference (the detector is moved).*



*Fig. 2. The machine bed as reference (the table is moved).*



**With the spindle laser D146 or the swivelling laser D22 mounted in the spindle of a machine tool. Place the Linebore detector D32 or the detector D5 in a suitable fixture to fit the holes in the workpiece that will be the reference for the alignment. Then a precise alignment can be done even when the distance between the spindle and the reference holes is very large.**





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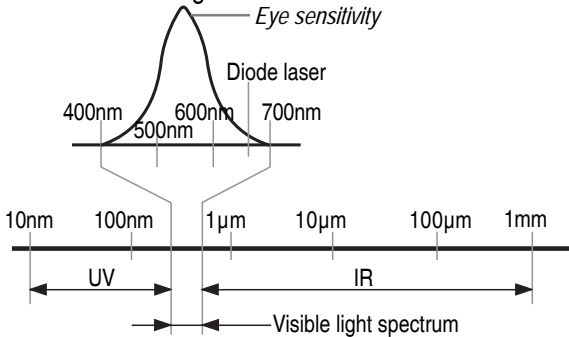
# *Measurement basics* E

## **E. Measurement basics**

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# FACTS ABOUT LASER

Light is a part of the electromagnetic spectrum, which also includes UV, IR, microwaves etc. Wavelengths between 400 nm and 780 nm are called visible light.



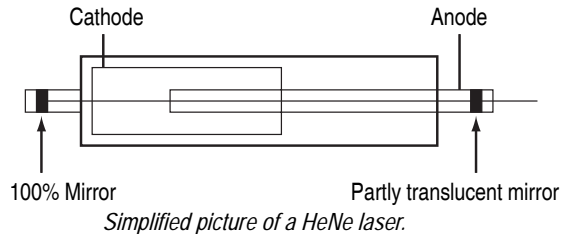
Electromagnetic spectrum

The word laser means: *Light Amplification by Stimulated Emission of Radiation.*

There are many applications for lasers and even more kinds of lasers to handle them. Instruments for length scale calibration (interferometers) of machine tools are most often equipped with gas lasers of helium-neon type. Within alignment instruments semiconductor lasers are the ones preferred. The benefits with this kind of lasers are the extremely compact design and very high directional stability of the beam.

To describe the laser principle we use a HeNe-laser because of its simplicity. The HeNe-laser consists of a glass tube with anode and cathode, filled with a mixture of helium and neon gas. At each end mirrors are placed, of which the one at the front is partially translucent.

The tube is powered from a high-voltage supply unit. The light is then generated by the electrical discharge in the gas (spontaneous emission), and begins to “bounce” between the mirrors. Only light that is moving exactly parallel to the length axis of the tube can go on bouncing and get so powerful (stimulated emission) that it can pass through the translucent mirror as a laser beam. In principle laser light is similar to normal light, but consists of light with only one wavelength.

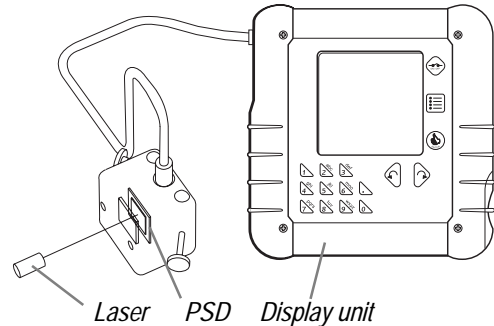
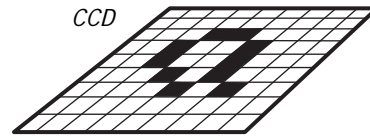
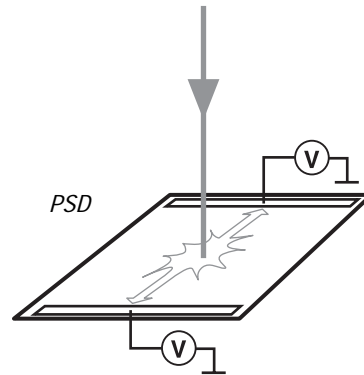


Laser diode (semiconductor type) as used in the Easy-Laser®.

**PSD is short for *Position Sensitive Device*.** The PSD detector consists of a light-sensitive silicon wafer. For comparison the PSD can be called an analogue component, with theoretically unlimited resolution, on the contrary to a CCD detector (camera device), which is digital and with a resolution limited by the design.

When the laserbeam hits the PSD, an electric current flows through the point hit by the beam. The electric currents at the two electrodes are proportional to the position of the beam. This makes it possible to determine the position of the beam center. The resolution possible is, quite literally, one in a million.

**Easy-Laser®** measurement systems uses a visible red laser beam as a measurement reference. The laser beam is directed to the PSD detector. Then the measurement programs in the Display unit calculate the values from the PSD and present the result according to which program is used.



# DIVERGENCE AND LASER BEAM CENTER

## Divergence

Every laser diverges i.e. the beam diameter increases with the distance depending on the type of laser. Normally lasers diverge with less than 1 mrad, i.e. the beam diameter increases with <1 mm/m. Due to their design, semiconductor lasers are always made with collimator optics. To reduce the divergence of the laser even more, telescopic optics can be used. The laser beam can then be focused at a specified distance, but the optics also enlarge the beam diameter at the aperture (see picture).

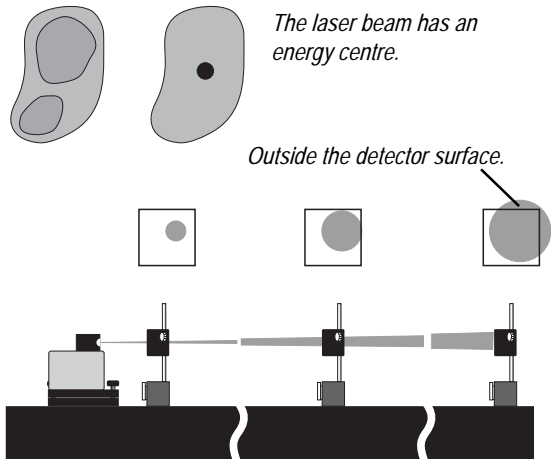
An example of a laser transmitter with telescopic optics is the Easy-Laser® D22.

## The centre of the laser beam

No laser beam is perfectly round. The energy from the beam is also somewhat different over the surface. But this is of no importance for the measurement result because the detector calculates/reads the energy centre for the beam, similar to how the centre of gravity of a body of any material can be calculated. Because of this it is however important that the whole of the beam hits inside the detector surface. It is the size of the detector surface in combination with the laser beam divergence that limits the possible measurement distance in each case.



*Laser divergence: A; plain. B; with telescopic optics*



*The laser beam has an energy centre.*

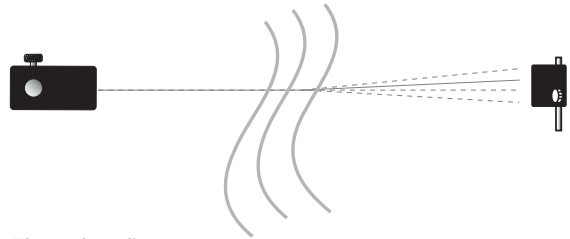
*Outside the detector surface.*

*Be sure that the whole beam hits the detector for correct calculation of laser energy centre (i.e. correct measurement value).*

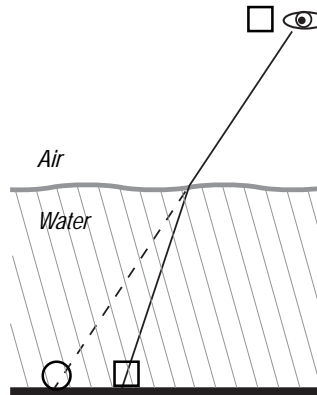
## Thermal gradients

You can easily see the effects of thermal gradients when the air is moving above the asphalt a hot summer day. It is then not possible to focus what is on the other side of this area. If the laserbeam passes through air with varying temperature, that may influence the direction of the laserbeam in the same way. During continuous measurement this could mean unstable readings. Try to reduce air movements between laser and detector by, for instance, moving heat sources, closing doors etc. If the readings remain unstable, you can use the measurement value filter feature in the Easy-Laser® systems.

*Always ensure a good measurement environment.*



*Thermal gradients*



*When you look down into the water, the light reflected from what you see at the bottom will deflect similar to the light from a laser when it breaks through two media, or two different temperatures of the same medium.*

**Demands on quality and performance** in the industry of today are increasing all the time. Down-time and maintenance need to be very well planned. When maintenance is done, there should be no doubt about the result. Using laser equipment is then a great advantage. With lasers the work is done very quickly, it can be done with very high precision and it can be documented. The measurement result will also be the same irrespective of who has done the work (unlike conventional methods).

**In this chapter we describe the fundamentals** within measurement and alignment, both laser and conventional methods. To get the most out of your Easy-Laser® measurement system it is important that you have fundamental knowledge about measurement. You will then do the measurements and alignments much faster and more accurately. In addition, you will doubtless see new possibilities to solve measurement problems you until then thought were hard, or even impossible to solve. Even if you have great experience in the field of alignment, you will probably get a better understanding of what to notice when doing the alignment work. At the same time you get an introduction to expressions and technical terms we use on other pages in this manual.

## **Shaft Alignment**

Almost 50% of all down-time in rotating machines depends on misalignment. Misaligned shafts can cause:

- Bearing failure*
- Shaft failure*
- Seal failure*
- Coupling wear*
- Overheating*
- Energy loss*
- High vibration*

Carefully aligned machines will get you:

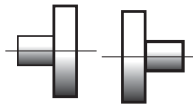
- Increased production time*
- Less bearing and seal wear*
- Less coupling wear*
- Less vibration*
- Lower maintenance costs*

**To be able to handle the measurement** equipment in the right way is an important part of the alignment. Knowledge about tolerances, different types of couplings, machines and foundations etc. is also necessary for a good result of the alignment work.

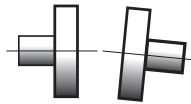
## Technical terms within measurement and alignment

that is important to know:

- Offset**                    *The centre lines of the two shafts are not concentric but parallel.*
- Angular deviation**    *The centre lines of the two shafts are not parallel.*
- M-machine**            *Movable machine. The machine that is adjusted relative to the stationary machine.*
- M-unit**                    *The measuring unit to be mounted on the movable machine.*
- S-machine**              *Stationary machine. Must not be moved.*
- S-unit**                    *The measuring unit that shall be mounted on the stationary machine.*
- Softfoot**                 *A condition where the machine stands on three feet instead of four. This of course means that the machine is standing unstably on the foundation. Should be adjusted before alignment.*



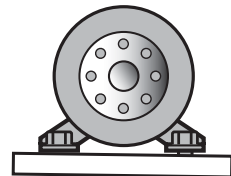
*Offset*



*Angular deviation*



*Offset and angular deviation*



*Softfoot*

## CONDITIONS FOR SHAFT ALIGNMENT

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### The conditions for a good alignment

Before you start the alignment you have to know how the machines will react in normal working conditions. To align machines that are in bad shape, or will move from their position just a short moment after starting them is a waste of effort.

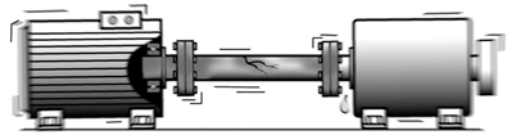
### New machines

Make a rough alignment, followed by a more accurate alignment when the installation is finished. Before alignment, check how the machine is working. Check the mounting bolts, coupling, vibrations, temperature, pipes and other connections.

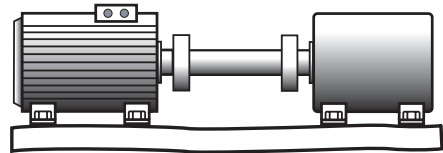
### Machine foundations (new installation)

Check that the foundations of both the machines are stable and flat, and that the concrete foundation has hardened before placing the machines. Observe that the feet of the machines should not rest directly on to the foundation, instead you should use shims. Clean the machine feet from dirt and rust. In addition the stationary machine should be shimmed a little bit higher than the moveable one before alignment.

To begin with, place approximately 2 mm of shims under each machine foot. Then you will be well prepared for the following alignment.



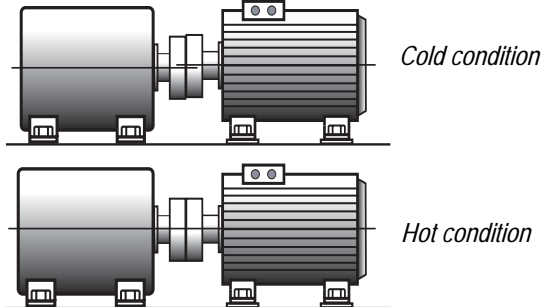
*Misaligned shafts will always cause strains and stresses in bearings, shafts, couplings and the driving machine.*



*Reliable alignment is not possible if the machine foundation is not stable.*

## Dynamical movements

During operation, machinery will be influenced by different factors and forces. These factors may be thermal growth, twisting forces, aerodynamical forces and hydraulic forces to mention some. The sum of these factors will result in an offset deviation from the position of a “cold” machine. This new position of the shafts is normally called the “hot” condition. Depending on the kind of machinery, these changes can be of great importance.



## Thermal growth

The result of the measurement can be influenced from different thermal growth factors for the S- and the M-machine. For example the thermal growth factor for steel is approximately 0.01 mm/m for each degree of temperature rising.

*Example:*

<i>Height from foundation to shaft</i>	<i>1 m</i>
<i>Temperature when aligning</i>	<i>+20 °C</i>
<i>Working temperature</i>	<i>+50 °C</i>
<b>Thermal growth:</b>	<b>1 x 0.01 x (50-20)=0.3 mm</b>

There is no problem when the S-machine has the same characteristics as the M-machine. In other cases you have to do the alignment before the machine get cold, or you have to compensate for the difference.

*Example:*

*If the S-machine rises with 0.25 mm more than the M-machine as a result of the thermal growth, the shims under the M-machine also have to be increased with 0.25 mm (under all feet).*

The machine manufacturers normally provide information about the thermal characteristics of their machines. Always check the following when deciding the influences of thermal growth:

- The working temperature for both the machines.*
- The temperature coefficient for both the machines.*
- The influence of the surrounding temperature such as machinery insulation, external heat sources, cooling systems etc.*

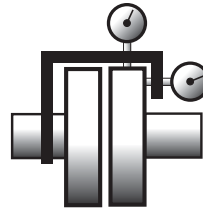
# SHAFT ALIGNMENT METHODS

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## Alignment methods

### *Rim and face method*

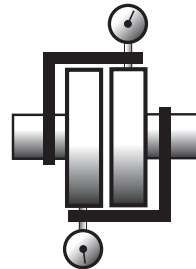
Two dial indicators mounted on a fixture indicate the offset (rim) and angular error (face) of the coupling. The readings are taken when the shafts are turned 180° between positions 6 - 12 - 9 - 3.



*Rim and face method.*

### *Reversed indicator method*

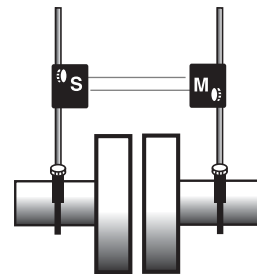
Two dial indicators, mounted on each half of the coupling shows the offset and angular error. Measurement values are read when the shafts are turned 180° between the measurement positions 6 - 12 - 9 - 3. One of the dials indicates the offset, and the difference between the dials gives the angular error.



*Reversed indicator method.*

### *Laser method*

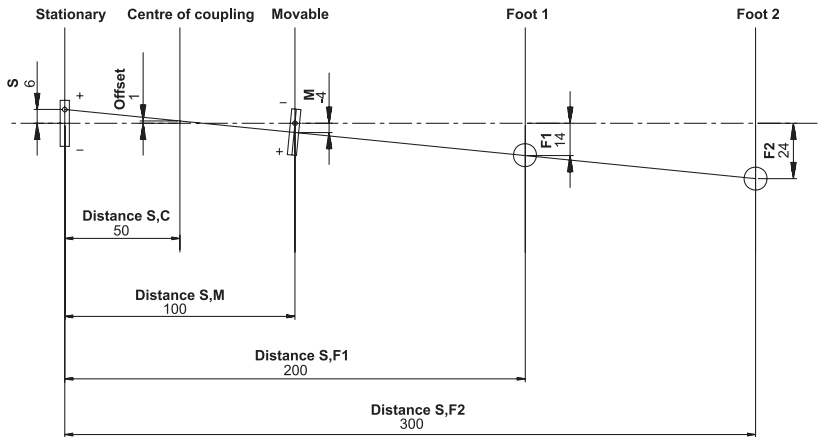
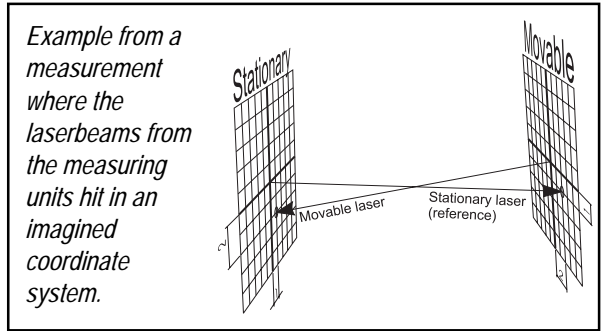
Works with the reversed method where, instead of dial indicators, two laser transmitters/detectors mounted on each part of the shaft/coupling are used. The measurement values are read when the shafts are turned to measurement positions 9 - 12 - 3, or with the program EasyTurn™ to three arbitrary positions with as little as 20° between the positions. The display unit calculates the offset and angular error, and also the position of front and rear feet pair. All values are displayed “live”.



*Laser method*

# MATHEMATICAL PRINCIPLES OF SHAFT ALIGNMENT

**Shaft alignment** with laser is based on normal trigonometrics, where the values are calculated by the display unit. The diagram below describes the mathematics behind the calculations.



$$\text{Foot position} = \left( \frac{M-S}{\text{Distance S,M}} \times \text{Distance S,Fx} \right) + S \quad F1 = \left( \frac{-4-6}{100} \times 200 \right) + 6 = 14 \quad \text{and} \quad F2 = \left( \frac{-4-6}{100} \times 300 \right) + 6 = 24$$

$$\text{Angle} = \frac{(M-S) \times 100}{\text{Distance S,M}} = \frac{-4-6}{100} \times 100 = -10/100$$

$$\text{Offset} = \left( \frac{M-S}{\text{Distance S,M}} \times \text{Distance S,C} \right) + S = \left( \frac{-4-6}{100} \times 50 \right) + 6 = 1$$

E

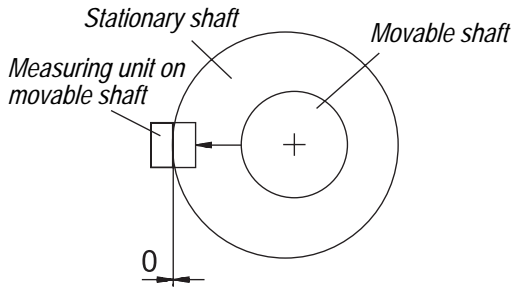
# CENTER OF ROTATION

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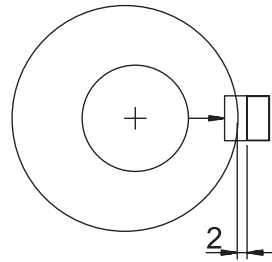
**Basic method** to find the centre of the shafts when doing *shaft alignment*.

*Example (only "movable" measuring unit shown):*

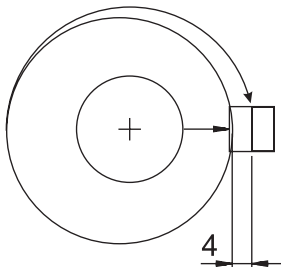
**1. Zero set.**



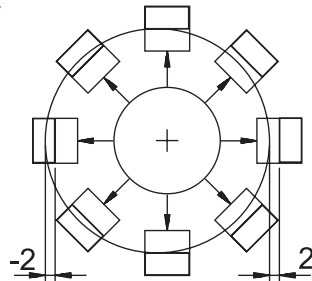
**3. Halve the value.**



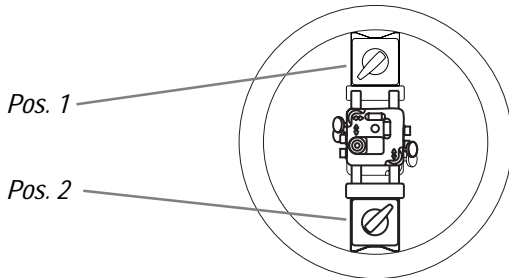
**2. Turn 180° and read the value.**



**4. Turn and read absolute values over one full revolution.**



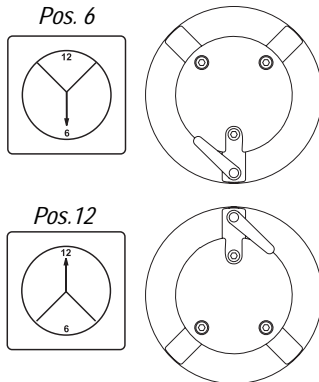
The centre of rotation for a detector when measuring centre of circle.



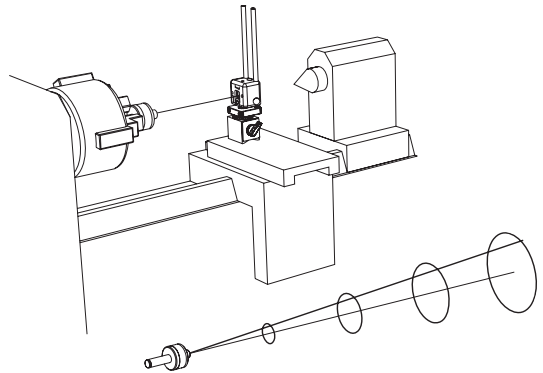
*When indexing the detector its centre of rotation is calculated relative to the laserbeam.*

*Zero the measurement values in position 1, and halve the values in position 2.*

*Now any different diameters will not affect the measurement value from being a true value of the centre point.*

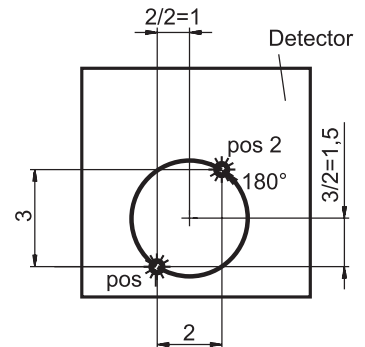


Centre of rotation for the laser when measuring pointing direction.



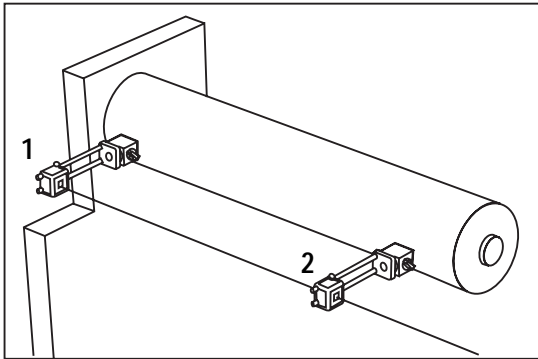
*The laser beam projects concentric circles. A line through two centre points will show the pointing direction of the spindle.*

*If the laser is indexed 180°, its centre of rotation will be calculated relative to the detector.*

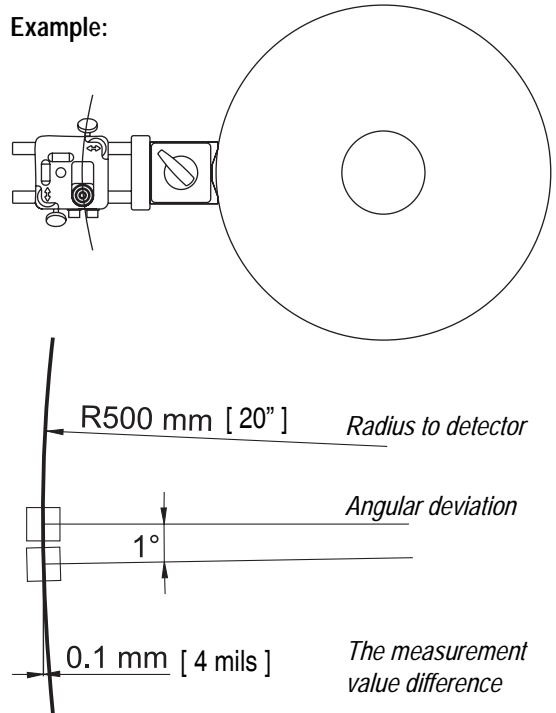


# ANGULAR DEVIATION

The position of the detector will influence the measurement value when measuring the parallelity between rolls. Therefore it is important to place the detector at the same angle at measurement positions 1 and 2 at each object.



Example:



At a radius of 500 mm [20"] an angular deviation of 1° will give a difference of 0.1 mm [4 mils] in radial measurement value.

All measurement with Easy-Laser® such as straightness, flatness, parallelism and squareness is based upon the same principle. All measurement values will reflect the position of the detector relative the laser beam. To be able to use the measurement values for adjustment and documentation, you need to select absolute references/zero points. These can be either points on the measurement object or the horizontal plane.

When using a horizontal reference, the laser beam is levelled to the vials on the laser transmitter.

When the measurement object is to be the reference, the laser is levelled to the detectors placed at the reference points.

This levelling is always carried out in the same way: *zero setting of the laser*.

## Zero setting of the laser

1. *Rough alignment to closed target.*

A- *At a short distance, aim the detector at the laser beam by sliding the detector on the risers.*

B- *At a long distance, level the laser to the target.*

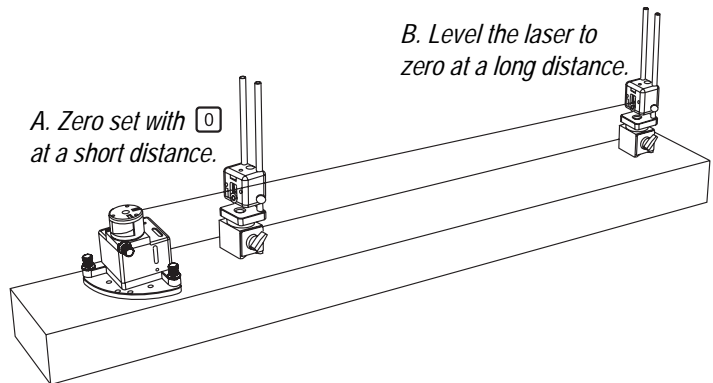
2. *Fine adjustment to open target.*

A- *At a short distance, zero set detector with  on the display unit.*

B- *At a long distance, level the laser to zero on the detector.*

C- *Redo steps 2A and 2B until you get zero at both of the reference points.*

*Now a measurement of the object along the laserbeam can be made.*



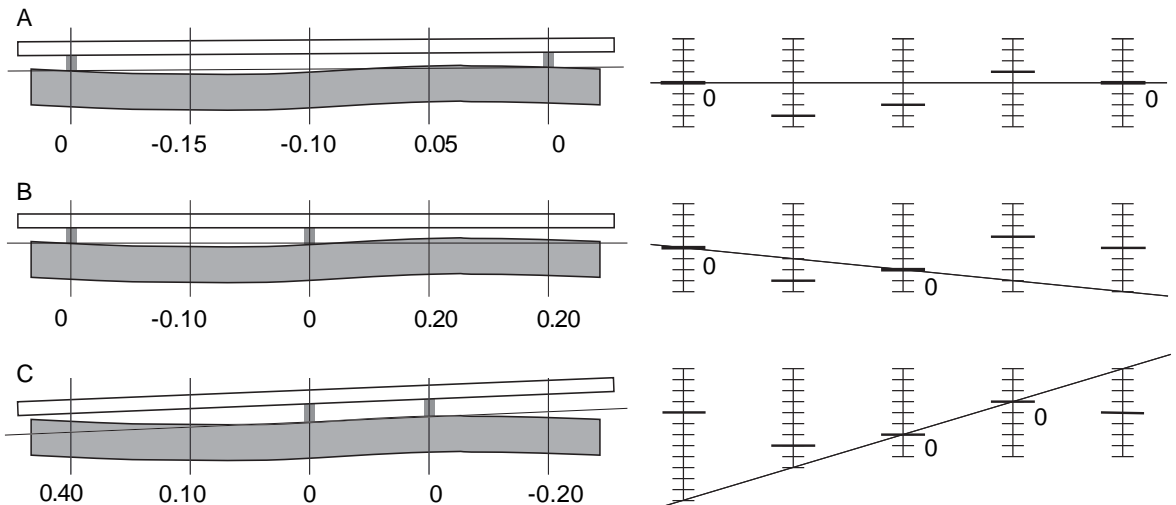
# STRAIGHTNESS – REFERENCE POINTS

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## Example of a straightness measurement

Taking a girder as example, we place our “zero points” (the gauge blocks under the straight edge) at different positions. The straight edge will now act as the reference line to which the other measurement values will refer. The measurement values are assumed according to example (A).

NOTE! The measurement values have been compensated for the thickness of the gauge blocks (represented in the picture by the thin line). If we then move the zero points (examples B and C), the measurement values will also change, corresponding to the reference line. In the same way as for the straight edge, the measurement values will change for an object measured with a laser system when the reference points are moved.



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# *Appendix*

**F**

## **F. Appendix**

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## TOLERANCES FOR SHAFT ALIGNMENT

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**The rotation speed of the shafts** will decide the demands on the alignment. The table on this side can be used as a guidance if no other tolerances is recommended by the manufacturer of the machines. The tolerances are set to the maximum allowed deviation from accurate values, with no consideration of whether that value should be zero or compensated for thermal growth.

	Excellent		Acceptable	
<b>Offset</b>				
<i>rpm</i>	<i>mils</i>	<i>mm</i>	<i>mils</i>	<i>mm</i>
<i>0000-1000</i>	<i>3.0</i>	<i>0.07</i>	<i>5.0</i>	<i>0.13</i>
<i>1000-2000</i>	<i>2.0</i>	<i>0.05</i>	<i>4.0</i>	<i>0.10</i>
<i>2000-3000</i>	<i>1.5</i>	<i>0.03</i>	<i>3.0</i>	<i>0.07</i>
<i>3000-4000</i>	<i>1.0</i>	<i>0.02</i>	<i>2.0</i>	<i>0.04</i>
<i>4000-5000</i>	<i>0.5</i>	<i>0.01</i>	<i>1.5</i>	<i>0.03</i>
<i>5000-6000</i>	<i>&lt;0.5</i>	<i>&lt;0.01</i>	<i>&lt;1.5</i>	<i>&lt;0.03</i>
<b>Angular error</b>				
<i>rpm</i>	<i>mils/°</i>	<i>mm/100</i>	<i>mils/°</i>	<i>mm/100</i>
<i>0000-1000</i>	<i>0.6</i>	<i>0.06</i>	<i>1.0</i>	<i>0.10</i>
<i>1000-2000</i>	<i>0.5</i>	<i>0.05</i>	<i>0.8</i>	<i>0.08</i>
<i>2000-3000</i>	<i>0.4</i>	<i>0.04</i>	<i>0.7</i>	<i>0.07</i>
<i>3000-4000</i>	<i>0.3</i>	<i>0.03</i>	<i>0.6</i>	<i>0.06</i>
<i>4000-5000</i>	<i>0.2</i>	<i>0.02</i>	<i>0.5</i>	<i>0.05</i>
<i>5000-6000</i>	<i>0.1</i>	<i>0.01</i>	<i>0.4</i>	<i>0.04</i>

## TOLERANCES FOR SHEAVE ALIGNMENT

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**Recommended maximum tolerances** from manufacturers of belt transmissions are, depending on type of belt, 0.25–0.5°.

$\angle^\circ$	mm/m mils/inch
0.1	1.75
0.2	3.49
0.3	5.24
0.4	6.98
0.5	8.73
0.6	10.47
0.7	12.22
0.8	13.96
0.9	15.71
1.0	17.45

*Recommended range*

# BTA DIGITAL; calibration

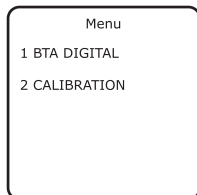
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## Calibrate the equipment

Now and then the BTA Digital equipment needs to be calibrated. This is done with the “Calibration” program according to the principle below.

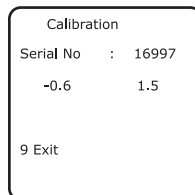
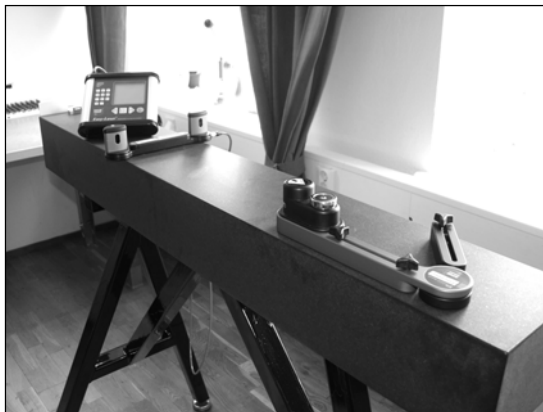
**1. Place the detector and the transmitter on a perfectly flat surface, e.g. a machine table. The purpose is to zero the measurement values when the magnet surfaces of the two units are truly parallel to each other, and not displaced.**

**2. Start the BTA DIGITAL program**




**3. Select 2, CALIBRATION**

Press **[2]**



**4. Calibrate the detector to 0 by first pressing **[0]**, then press **[8]** “Save”.**

*Now the detector unit is calibrated to the laser transmitter.*

[ To interrupt the calibration, press **[9]** “Exit”, or turn the display unit off with . If you choose Exit you will come to the measurement procedure step 3. ]

## CHECKING THE DETECTOR READINGS

**A method to check** if the Easy-Laser® measuring units are within the specified tolerances.

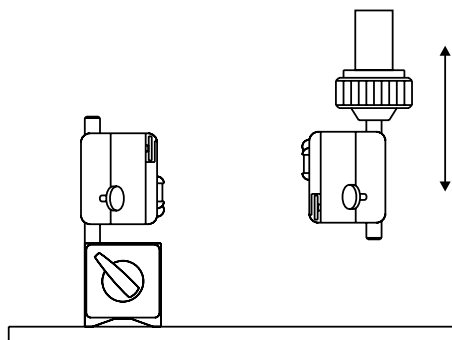
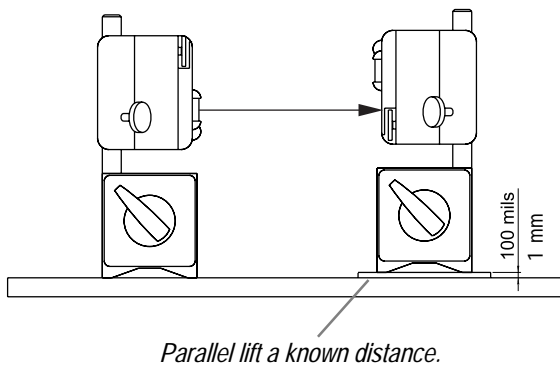
1. Use program Values. Set the resolution to 0.5 mil [0.01 mm], display the M-values and set to zero by pressing the **0** button.

2. Put a shim under the magnet base to lift the M-unit 100 mils [1 mm] and the M-reading shall correspond to the movement within 1 % (1 mil ± 1 digit) [0.01 mm ± 1 digit).

3. Remove the shim, display the S-values, set to zero and put the shim under the magnet base to lift the S-unit. S-reading shall now correspond to the movement within 1 % (1 mil ± 1 digit) [0.01 mm ± 1 digit).

### Note!

It is only the lifted unit that can be measured each time.



# CONVERSION TABLES

Conversion tables to convert measurement values from one unit to another.

## Mass

gram (g)	ounce (oz)	pound (lb)
1	0.035	
28.35	1	
453.59	16	1
1000		2.205

## Length

mil	mm	Inch	Foot	meter
0.0394	0.001			
0.05	0.00127			
0.3937	0.01			
0.5	0.0127			
1	0.0254	0.001		
3.937	0.1	0.0039		
5	0.127	0.005		
39.37	1	0.0394		
100	2.54	0.1		
1000	25.4	1	0.0833	
	304.8	12	1	0.3048
	1000	39.37	3.28	1

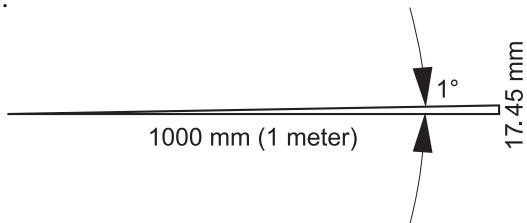
## Angle

arc sec.	mil/foot	mil/inch	mm/m	degree	inch/foot
1	0.06	0.005	0.005		
16.6	1	0.083	0.083		
	12	1	1	0.057°	0.012
	210	17.45	17.45	1°	0.21
	1000	83.3	83.3	4.75°	1

## Temperature

°C	°F
-40	-40
-30	-22
-20	-4
-17.8	0
-10	14
0	32
10	50
20	68
30	86
37.8	100
40	104
50	122
60	140
70	158

Example:



### A. The system will not start:

- 1 Don not let go of the *On*-button so quickly.
- 2 Check that the battery poles are facing the correct side according to the labels.
- 3 Change batteries.

### B. The laser does not light up:

- 1 Check the connectors.
- 2 Change batteries.

### C. No measurement values are displayed:

- 1 See B
- 2 Open the target.
- 3 Adjust the laser to the detector.

### D. Unstable measurement values:

- 1 Tighten the screws at the fixtures etc.
- 2 Adjust the laser away from the PSD edge.
- 3 Increase the filter setting (not for BTA digital).

### E. Wrong measurement values?

- 1 Study arrows and signs on the detector labels.
2. BTA digital; check mounting direction of detector unit.

### F. There is no printout from the printer:

- 1 Check the printer cable.
- 2 If red diode on the printer goes out, charge the printer batteries.

### Cleaning

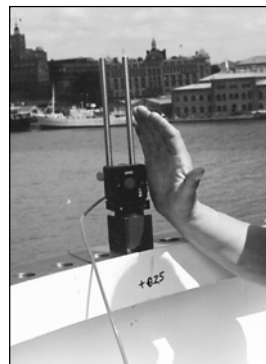
For the best measurement result, always keep the equipment clean and the optics at the detector and laser very clean from dirt and fingerprints. Use a *dry* rag for cleaning.

### Batteries

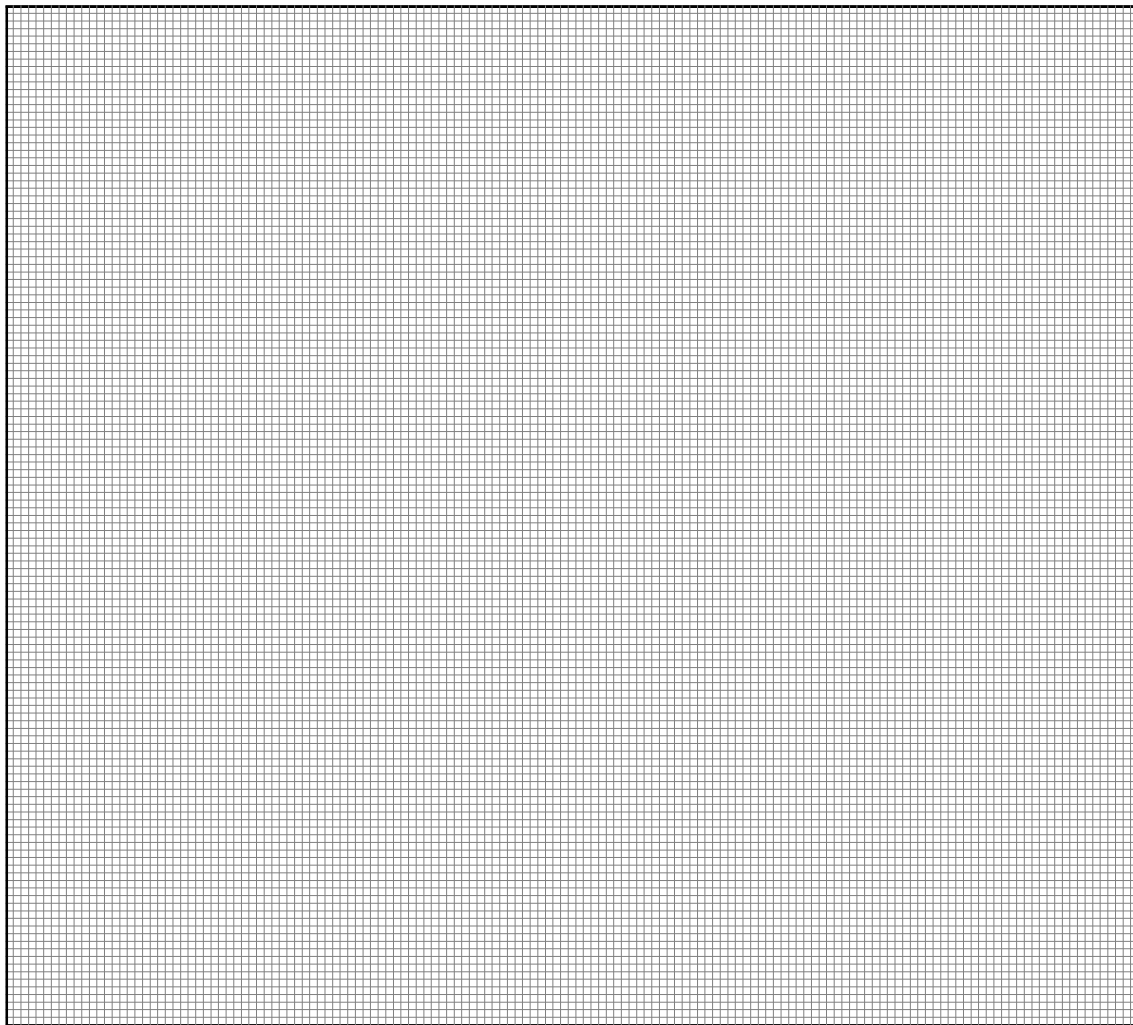
The system is powered by four R14 (C) batteries. Most types of batteries can be used, even rechargeable, but alkaline will give the longest operating time. If the system will not be used for a long time, the batteries must be taken out.

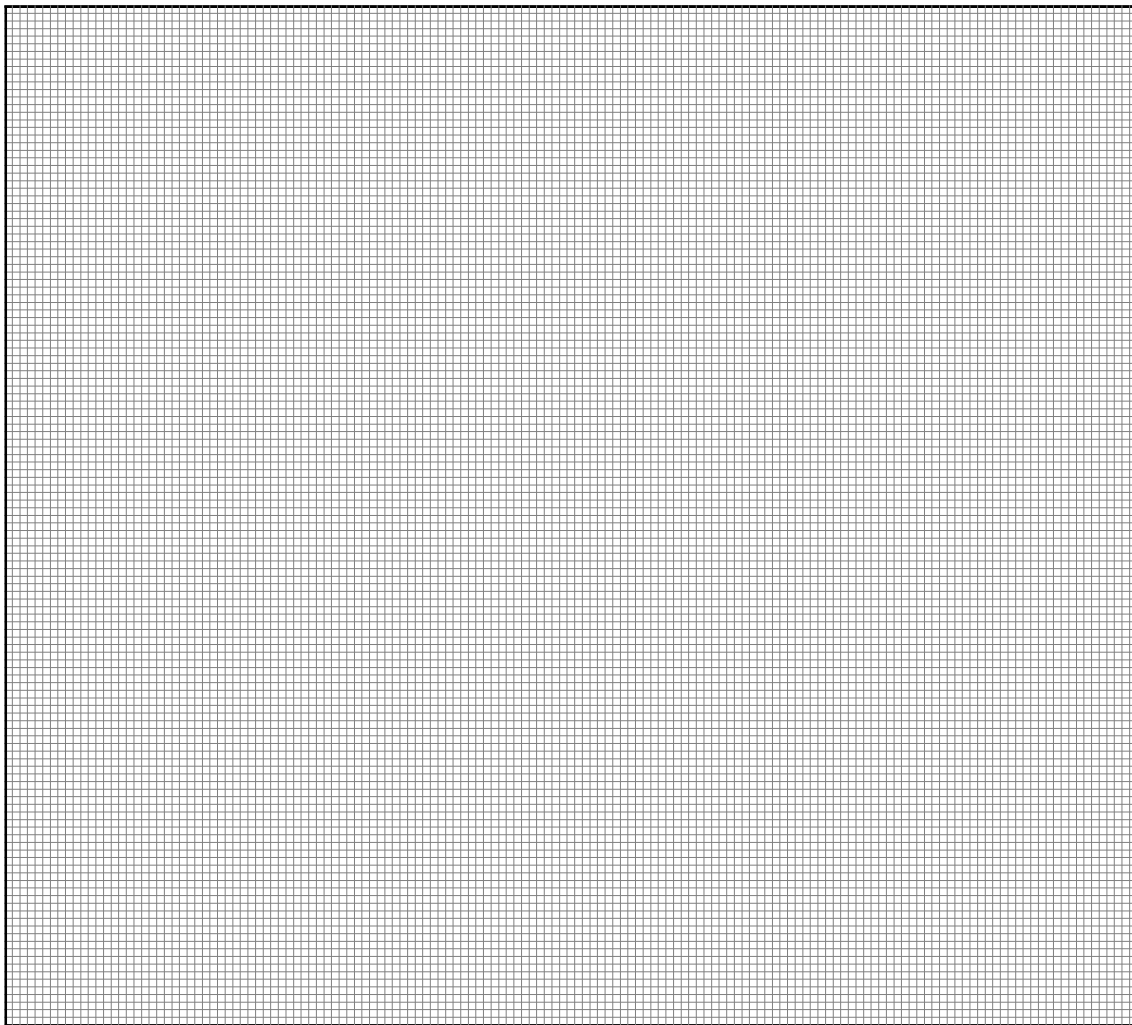
### Avoid direct sunlight

If the measuring unit/detector has to be placed so that sunlight hits the PSD directly, there is a risk of unstable measurement values. Try to shade the detector, for example as shown in the picture.



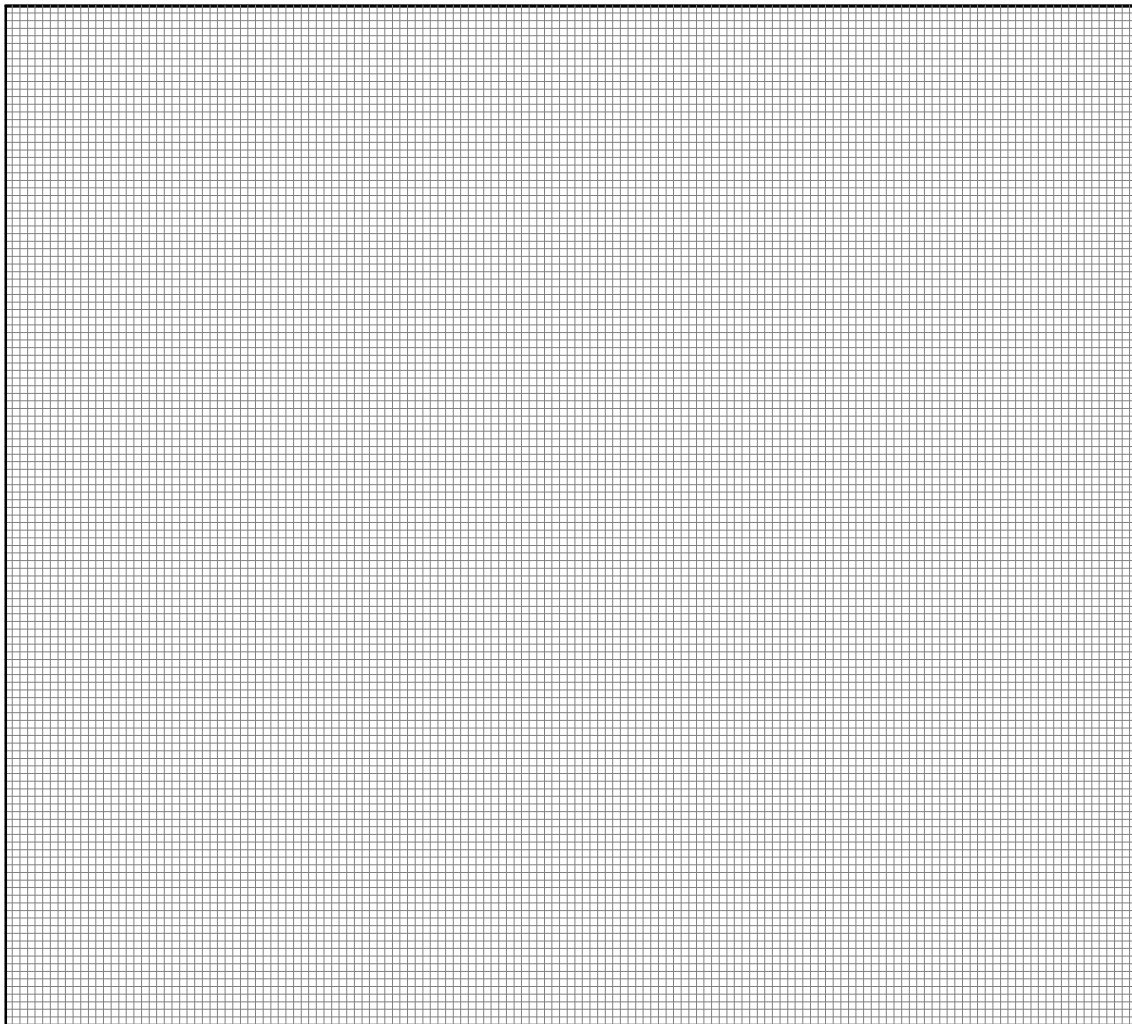
# NOTES

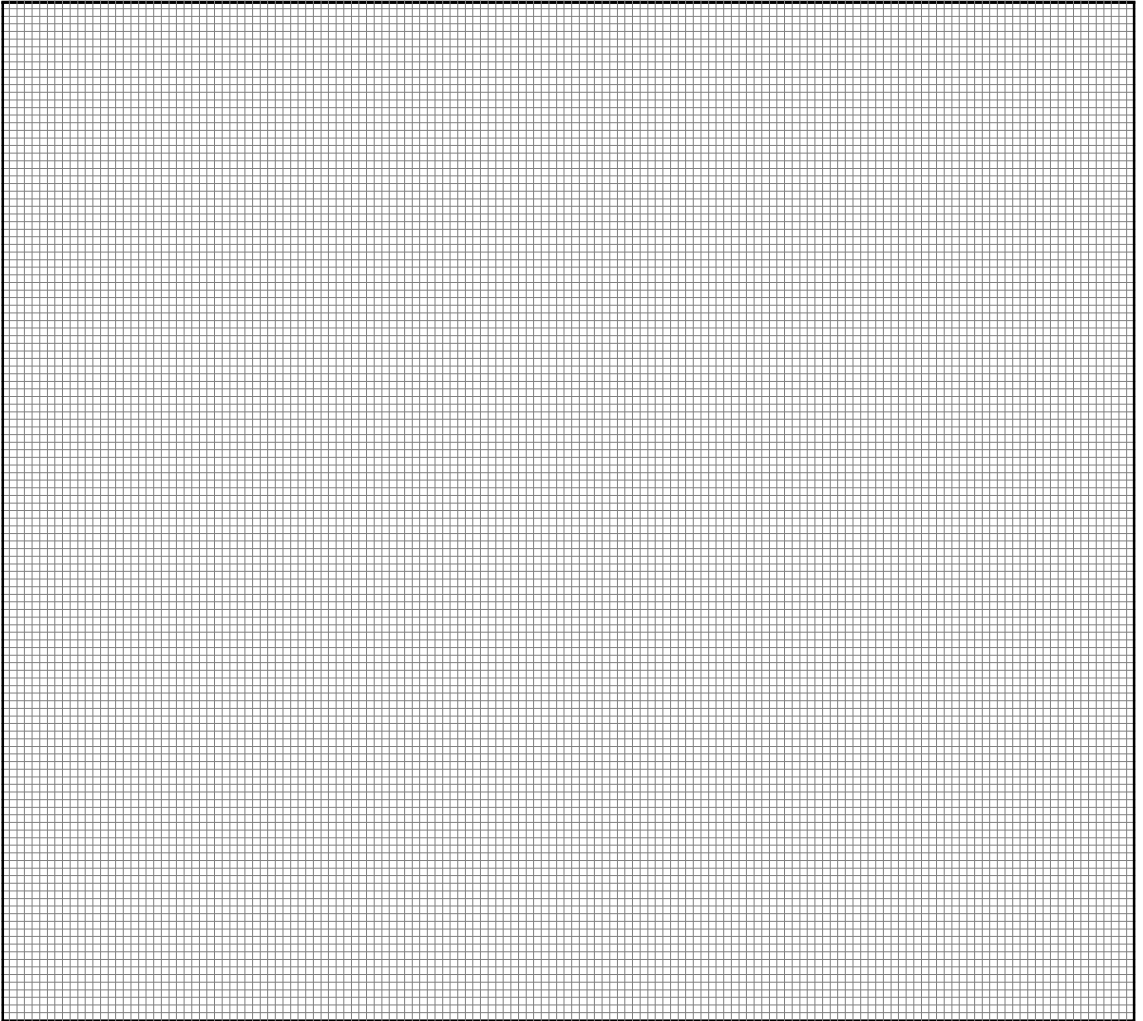




**F**

# NOTES





# NOTES

