Laser Interferometer **LP30 -3D**

User manual

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LP30-3D 三维激光干涉仪

User manual

用户手册

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INTRODUCTION

引言

Laser measurement system ***LP30-3D*** is a two frequency interferometer for inspection of machine tools and calibration of coordinate measuring machines CMM. Its small size and low weight simplify transportation and make the instrument especially useful for service applications. Software version for Windows 9x/NT/2000/XP and automation of measurement process make the interferometer easy to use. Software and reports are compliant to ISO/DIS 230 and PN–93 M55580 standards. Following standards are included: ISO 230-2 (European), VDI/DGQ 3441 (German), NMTBA (USA), BSI BS 4656 Part 16 (British) and PN-93 M55580 (Polish).

Extremely high technical parameters of the interferometer allow using it as an absolute length reference in scientific and calibration laboratories, for precision positioning systems, for upgrade of length measurement systems, etc.

LP30 - 3D 三维激光测量系统是双频激光干涉仪，主要用于机床的检测和三坐标测量仪的校准。它尺寸小，重量轻，运输方便，应用很方便。软件版本兼容 Windows 9x/NT/2k/XP，测量过程的自动化使干涉仪易于使用。软件和报告符合 ISO /DIS 230 和 PN - 93 M55580 标准。符合的其他标准还包括：ISO230-2（欧洲），VDI/ DGQ 3441 （德国），NMTBA （美国），BSI BS 4656 的 16 部分 （英国）和 PN - 93 M55580 （波兰）。

本激光干涉仪技术参数极高，可以把它作为绝对长度参考，用于科学和校准实验室，精密定位系统，长度测量系统升级等。

Safety considerations

安全考虑

The Laser Interferometer ***LP30-3D*** is a Safety Class I product designed and tested in accordance with international safety standards. It is also a Class II Laser product conforming to international laser safety regulations. The instrument and the manual should be inspected and reviewed for safety markings and instructions before operation.

LP30 - 3D 激光干涉仪是 I 级安全产品，设计和测试都符合国际安全标准。它同时也是 II 级激光产品，符合国际激光安全规则。该仪器及手册应在操作之前进行安全标记和用法说明审查。

Warnings

警告

Although the laser measurement system ***LP30-3D*** was design to be used in harsh environments, the following conditions **must** be met:

- The laser head **must not** be put near strong magnetic fields.
- The head should not be unscrewed from its base and if it is, it **may not** be put on a heat sink (e.g. thick metal plate).
- The head **must not** be thrown or dropped.
- Keep the optical components clean and avoid scratching them.
- When the optics is dusted, clean it with pure alcohol.
- Do not use the system outside its work conditions.

虽然 LP30 激光测量系统设计可用在恶劣环境中，下列条件必须满足：

- 激光头必定不能靠近强磁场。
- 激光头不应该从基座上拧下来，如果万一拧下来，它绝对不能放在散热片上（如厚金属板）。

- 激光头不得抛掷或摔落。
- 保持光学元件清洁，避免划伤。
- 当光学元件有灰尘时，用纯酒精清洗。
- 不要使用超出其工作条件的系统。

2

PRINCIPLES OF OPERATION

操作原则

Basics of laser displacement measurements

Displacement measurements with the use of a laser interferometer allow obtaining the accuracy of a displacement of 0.4 ppm in air and 20 nm in vacuum. The interferometer was first built by A. A. Michelson in 1881. The simplified schematic of the interferometer is shown on fig. 2.1.

Coherent light beam falls on a semi-transparent mirror. This mirror splits the light into two beams. The first beam goes to the reference arm and reflects from the reflector Z_1; the second goes to the measurement arm and reflects form the reflector Z_2. The reflected beams meet again on the detector. Because these beams come from the same, coherent, source, they will interfere. When the moving reflector is being displaced, the frequency of the reflected beam in the measurement arm changes. The detector counts the frequency difference between reflected beams - f_D (see fig. 2.1). The measured value of the displacement is calculated according to

激光位移测量基本原理

使用激光干涉仪测量位移，可在空气中获得 0.4ppm 位移精度，可在真空中获得 20nm 的位移精度。干涉仪最早是麦克逊在 1881 年建成的。该干涉仪的简化原理图如图（2.1）所示。

相干光束打在半透明的镜子。这种镜面把光线分成两个光束。第一光束打在参照臂上，从反射器 Z1 反射，第二光束打在测量臂上，从反射器 z2 反射。反射光束会在探测器上再次相遇。由于这些光束来自相同的，一致的光源，他们会干涉。当移动的反射器被转换时，测量臂上反射光束的频率

就会变化。探测器就能计算反射光束频率差。（见图 2.1）位移测量值的计算是根据：

$$L = f_D * \frac{\lambda}{2} = N * \frac{\lambda}{2} \qquad (1)$$

Where（其中）： N – number of pulses（脉冲数）

λ - light wavelength（光的波长）

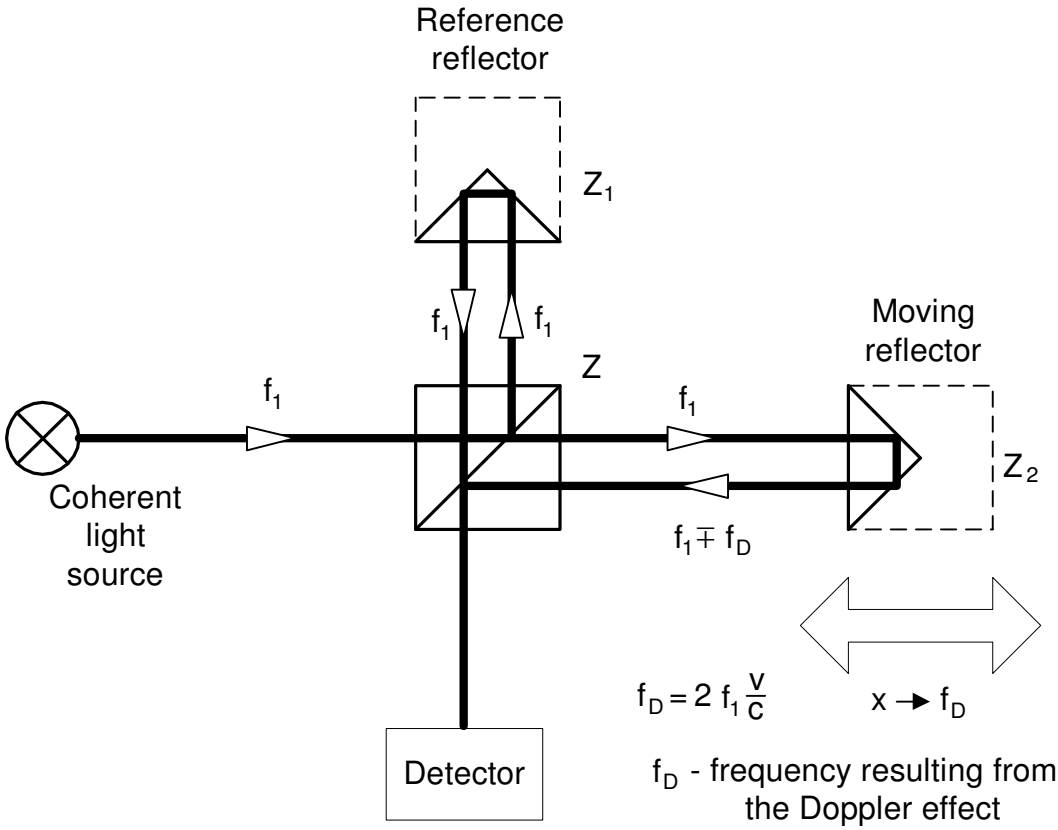


FIG.2.1. *THE MICHELSON INTERFEROMETER.*（麦克逊干涉仪）

Reference reflector ： 参照反射器

Coherent light source： 相干光源

Moving reflector: 移动反射器

Detector: 探测器

Doppler effect： 多普勒效应

The construction of real interferometers

The main disadvantage of Michelson interferometer results from the fact that the detector cannot determine, whether f_D is negative or positive thus, from the measurements the displacement of the moving reflector without the sign is obtained. Currently there are widely used two methods that allow getting also the direction of the movement. Depending on the number of light frequencies (wavelengths) used in the interferometer; the first is called *homodyne* (one frequency) and the second *heterodyne* (two frequencies) method.

In the homodyne method, shown on figure 2.2, as a coherent source of light a linearly polarized laser is used. If it is two-mode laser (i.e. it generates two wavelengths) than one mode must be cut off with the use of a properly set polarizer. The polarising splitter splits the light beam from the laser into two beams polarized vertically (90^o) and horizontally (0^o). The former is directed to the measurement arm and the latter to the reference one. The frequency of the beam in the measurement arm changes with the movement of the moving reflector. The polarization of the reflected beams is changed to circular with the use of a λ/4 waveplate. After 0° and 45° polarisers, two signals shifted in phase are obtained. The phase shift is $+90^o$ when the measurement arm moves towards the laser and -90^o when it moves from the laser.

真正干涉的建立

麦克逊干涉仪的主要缺点来自一个事实，即探测器无法确定 f_D 是正的还是负的，因此从这种测量中，只可以得到没有正负标志的移动反射器的位移。目前，有广泛使用的两种方法也可以得到运动的方向。根据干涉仪使用的光频率数（波长）的不同，第一种被称为零差（一个频率）法，第二种被称为外差（两个频率）法。

零差法中，如图 2.2 所示，作为相干光源，线性偏振激光被使用。如果是双模激光（即生成双波长），必须切断一个正确设置的偏光器的使用。分路器的把光束分成两个垂直的激光光束，纵向（90°）和横向（0 °）。前者指的是测量臂，后者指的是参照臂。测量臂的光束频率随移动反射器的运动而变化.反射光束偏振变为圆形，在使用λ/4 波片之后。经过 0 °和 45 °偏光器，得出两个信号同相转换。当测量臂向激光移动时，周相移动是+90°，从激光向测量臂移动时，周相移动是-90°。

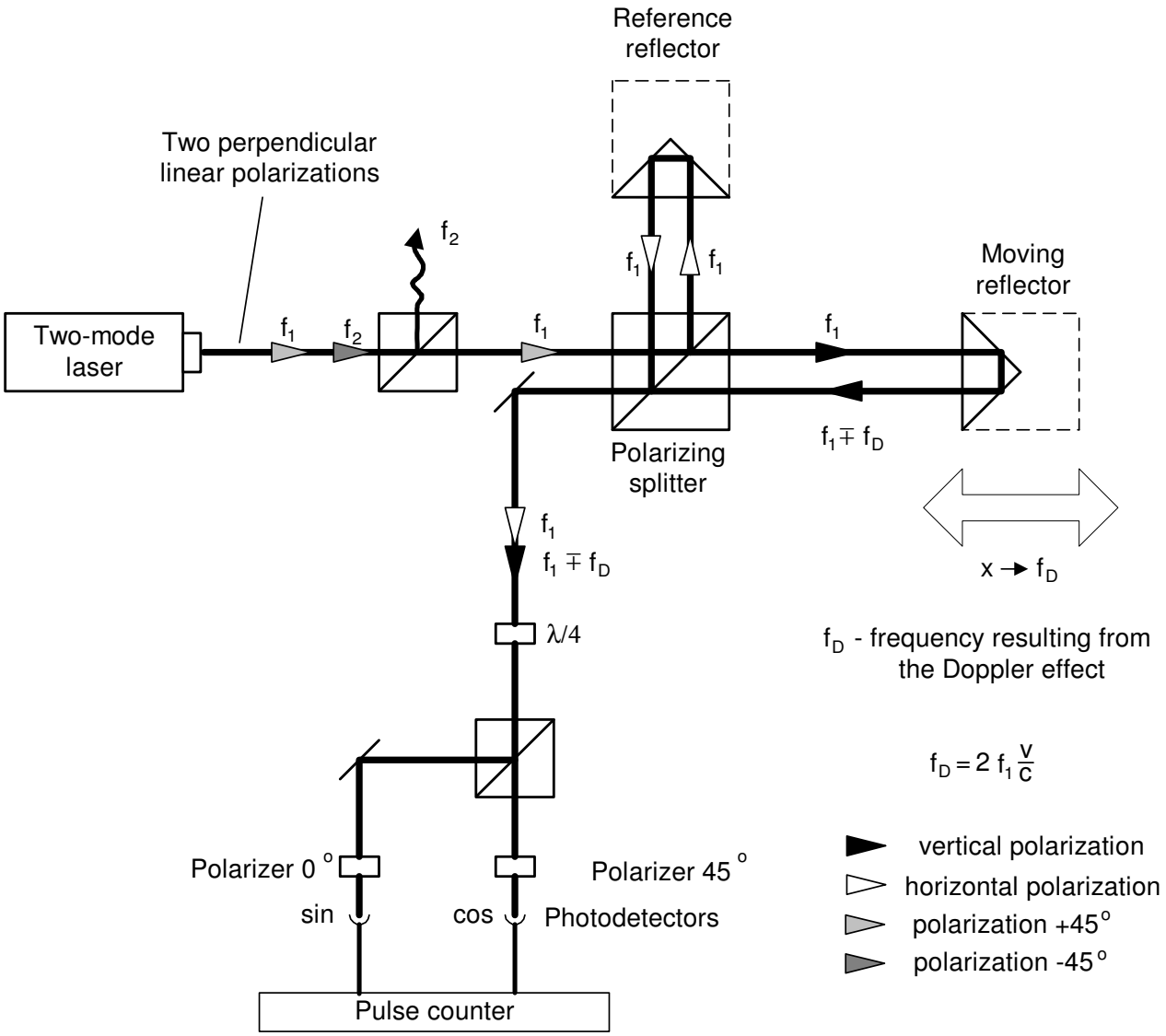


FIG.2.2. *THE BLOCK DIAGRAM OF AN INTERFEROMETER WORKING ACCORDING TO THE HOMODYNE METHOD.*（零差法激光干涉仪结构图）

Perpendicular linear polarizations: 垂直线性偏振

Polarizer： 偏光器

In the heterodyne method, shown on figure 2.3, two different laser frequencies are used. Therefore a two-frequency laser is needed (Zeeman laser). A two-mode laser is not suitable for the heterodyne method interferometer, because the difference between f_1 and f_2 is usually too high for an electronic counter. The output beam of a Zeeman laser consists of two circularly polarized beams, one polarized leftward and the second rightward. A λ/4 waveplate changes circular polarization to linear. The main difference between the two methods described here, is that in the heterodyne one the beam frequency in reference arm differs from the beam frequency in the measuring arm. The detection path is also different – the measurement is performed by subtracting frequencies of reference and measuring arms.

在外差法中，如图 2.3，使用两个不同的激光频率。因此，需要双频激光（塞曼激光器）。双模激光不适合外差法干涉仪，因为 F1 和 F2 之间的差距往往对于电子计数器过高。一个塞曼激光器的输出光束由两个圆偏振光组成，第一个向左，第二个向右。一个 λ/4 波片把圆偏振变为线性。这两种方法之间的主要区别是，在外差法中，参照臂的光束频率与测量臂的光束频率不同。该探测路径也不同-测量是减去参照臂和测量臂的频率进行的。

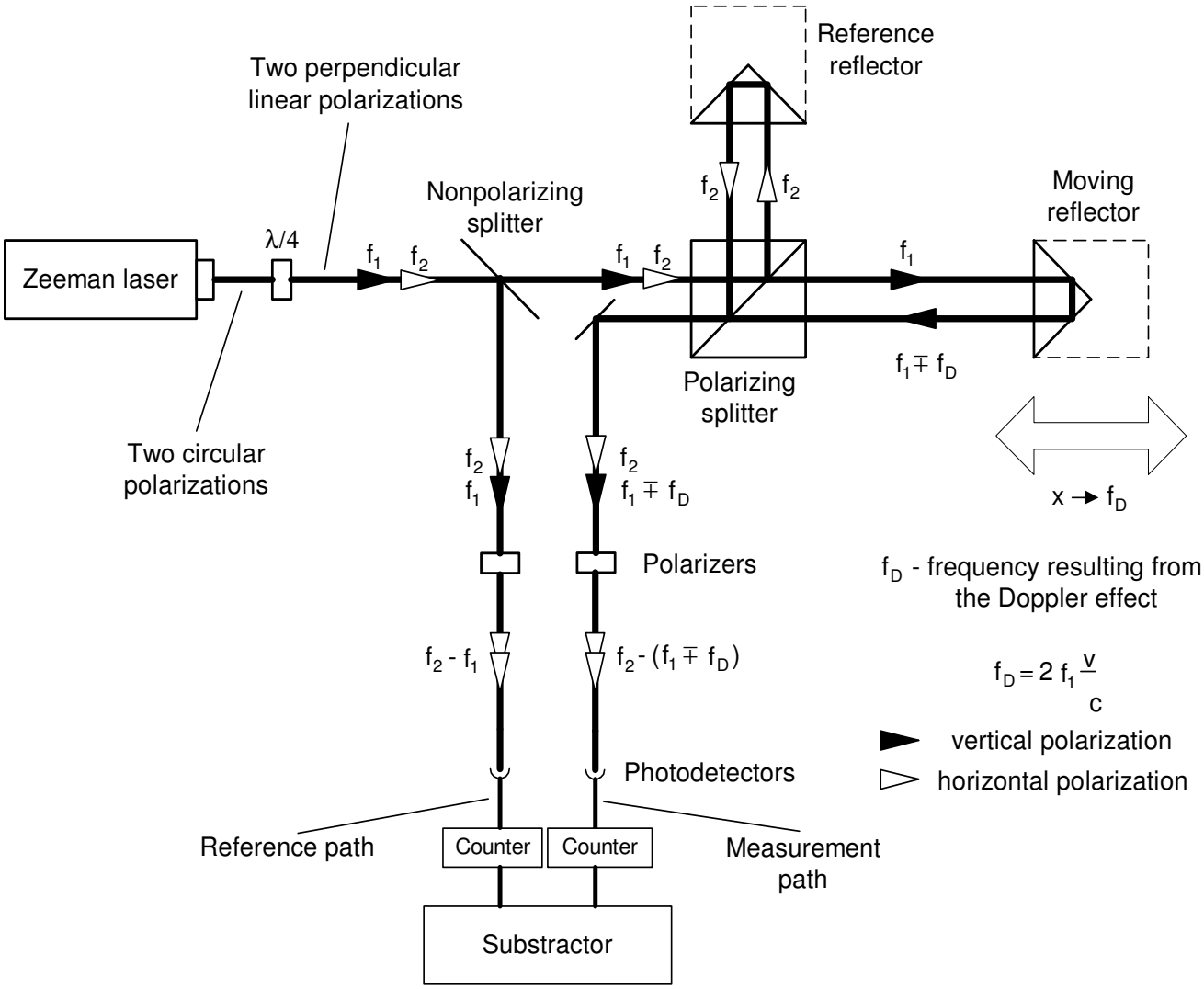


FIG.2.3. *THE BLOCK DIAGRAM OF AN INTERFEROMETER, WORKING ACCORDING TO THE HETERODYNE METHOD.*（外差法干涉仪结构图）

Subtractor： 减法器

Photodetector: 光电探测器

The heterodyne method gives correct results only when f_D does not exceed the difference between the laser frequencies, i.e.: $f_2 - f_1$. In reality, that difference, resulting from the Zeeman effect, is about 1MHz. **This fact limits the maximum available velocity of the measuring arm, in one direction, to 0.3 m/s.** The next disadvantage of the heterodyne method is, that two frequencies must be used for measurements, while in the homodyne method the second may be used for measuring e.g. a second axis.

外差法给出正确的结果，只有当 f_D 不超过激光频率的差别时，即：F2- F1 的差别。在现实中，这种差别产生自塞曼效应，约 1MHz。这一事实限制了测量臂的最大可用速度，在一个方向，到 0.3 米/秒。外差法的另一个缺点是，这两个频率必须用于测量，而在零差法中，第二个频率可用于测量（比如）第二个轴。

The influence of the outside conditions on the measurement accuracy

外部条件对测量精度的影响

According to equation (1) an interferometer's unit of measure in length measurement is laser's wavelength. From definition

$$\lambda = \frac{v}{f} \qquad (2)$$

a wavelength depends on laser's frequency f and the speed of light v in the measuring path. If the measurement is done in vacuum, then $\nu = c = 3*10^8$ m/s. The speed of light in a medium other than vacuum (e.g. air, water) is lower and is described as 根据方程（ 1 ），干涉仪的长度测量单位是激光的波长。从定义 $\lambda = \frac{v}{f}$，波长取决于测量路径上的激光频率 f 和光速 v,如果测量是在真空中进行的， 那么 $\nu = c = 3*108$ m/s. 光速在非真空的媒介中低一些，公式是：

$$v = \frac{c}{n} \qquad (3)$$

Where: n – a refraction coefficient.（折射系数）

Normally the refraction coefficient n is a complex variable or even a tensor, but for less accurate calculations it is simplified to a constant. The air coefficient depends mostly on the pressure P, temperature T and humidity H. The dependence $n_{T,P,H}$, for the air was empirically determined by Edien and is described as

通常，折射系数 n 是一个复杂的变量或者张量，但在不太精确的计算中它就被简化为一个常数。空气系数主要取决于压力 P，温度 T 和湿度 H. 空气耐受性 $n_{T,P,H}$ 是 Edien 凭经验确定的, 被描述为

$$n_{T,P,H} - 1 = 2{,}8775 * 10^{-7} * P \frac{1 + 10^{-6} * P * (0{,}613 - 0{,}00997 * T)}{1 + 0{,}003661 * T} + \Delta n \qquad (4)$$

$$\Delta n = -3{,}033 * 10^{-9} * H * e^{0{,}057627 * T} \qquad (5)$$

From the above equations one may obtain the refraction coefficient dependences on T, P and H in usual conditions (T=293K, P=1000hPa, H=50%):

从上述方程，人们可以获取折射对 T，P 和 H 在通常情况下的系数（耐受性）（T= 293K，P = 1000hPa，H= 50%）：

$$\frac{\partial n}{\partial T} = -0{,}93 * 10^{-6} \left[\frac{1}{K}\right]$$

$$\frac{\partial n}{\partial P} = +0{,}27 * 10^{-6} \left[\frac{1}{hPa}\right]$$

$$\frac{\partial n}{\partial H} = -0{,}96 * 10^{-8} \left[\frac{1}{\%}\right]$$

It is worth to notice that the most critical parameter is the temperature, because its change influences the coefficient n more than changes in the pressure and much more than changes in the humidity.

值得注意的是，最关键的参数是温度，因为它的变化影响到系数 n，超过压力的变化，更远远超过湿度的变化对系数 n 的影响。

The accuracy of laser interferometers

激光干涉仪的精度

Errors caused by the environment

环境所造成的误差

The most impotent source of errors in machine geometry measurements is the temperature (or more exactly, the change of the temperature) of the measured machine. For example, if the machine's base is made of steel, then the base's length increases 11.7μm when its temperature changes 1K. It shows how important it is for very precise measurements to measure the temperature of the controlled part of the machine and to use it in readout corrections. This is not a simple task for a few reasons, but the most important one is that, than when the machine operates, there are temperature gradients on it. That means that more than one temperature sensor is needed and that the more sensors are used the better accuracy can be achieved. Moreover the shape of the measured part of the machine may "absorb" a part of the expansion of the material or the part may be built of materials of different expandability.

As was mentioned in the previous chapter, the temperature influences the accuracy also as it changes the refraction coefficient of the medium the measurements are made in (usually it is air, but may be e.g. water). An Edien equation was presented, showing how the refraction coefficient of the air changes with the change of the air temperature, pressure and humidity. The errors caused by the change of the wavelength are less important than the mentioned above, but they cannot be abandoned. Roughly, a 1ppm error (i.e. 1μm/m) is caused by: the air temperature change of o 1K, the air pressure change of 4hPa and the air humidity change of 30%.

在机器的几何尺寸测量中，最无能为力的误差来源是所测量机器的温度（或更确切地说，温度的变化）的测量机。例如，如果计算机的基座是钢制成的，那么当温度变化 1k 的时候，基座的长度增加 11.7μm. 这表明，测

量机器的控制部分的温度对非常精确的测量是多么重要，并把它用于读出更正中。这不是一个简单的任务，有几个原因，但最重要的是，当机器运作时，温度梯度是存在的。这意味着，需要一个以上的温度传感器，传感器越多，更好的准确性可以实现。另外，这类机器的被测工件形状可能会“吸收”材料扩张的一部分，这部分有可能是不同的扩展性材料建造的。正如在前面章节中提到的，温度影响准确性，因为它改变所做测量的介质的折射系数（一般是空气，但有可能是水）。Edien 方程，说明空气的折射系数如何随空气的温度，压力和湿度的变化而变化。由波长的变化造成的误杀没有上述变化造成的误差那么重要，但也不能忽略。粗略地讲，1ppm（即 1μm/m）的误差是由 IK 气温变化，4hPa 空气压力的变化和 30％的空气湿度变化造成的。

Dead path error

死路径误差

A dead path error is an error associated with the change in environmental parameters during a measurement. This error occurs when some part of the light path (a *dead path*) is not included in the temperature (both air and base), pressure and humidity compensation.

The *dead path* of the light path is a distance between the optical interferometer and the base (or the null point) of the measuring position (L_1 on figure 2.4). Let the position of the interferometer and the retro-reflector do not change. When there is a change in the air temperature, pressure or humidity, then the wavelength changes on the whole path length ($L_1 + L_2$). The path length changes also when the temperature of the base changes. But the correction system will use the correct wavelength only on the length L2 and will correct only this length. The correction will not be made on a dead path L_1. In this way, the laser system will “move” the base point.

The higher is the distance between the interferometer and the base point, the higher is the dead path error. **This error is especially important in laser interferometers where the interferometer is build-up in a common casing with a laser head, because it is then very difficult to reduce it.**

一个死路径误差是测量过程中与环境参数的变化相关联的误差。此误差发生在光路（一个死路径）的部分未能包括在温度（包括空气和基座），压力和湿度的赔偿中。

光路死路径是指光学干涉仪和基座（或零点测量位置）（图 2.4 中 L1）的距离。让干涉仪和反射器的位置不变。当有一个空气的温度，压力或湿度变化，那么波长整个路径的长度都会变化（L1 + L2)。路径长度也会变化，当该基座的温度变化时。但是，校正系统将只使用 L2 正确的波长，并只校正本长度。L1 的死路径不会得到更正。这样，激光系统将“移动”基点。干涉仪和基座的距离越大，死路径误差越高。此误差对于带有一般的激光头的激光干涉仪来说特别重要，因为它很难降低。

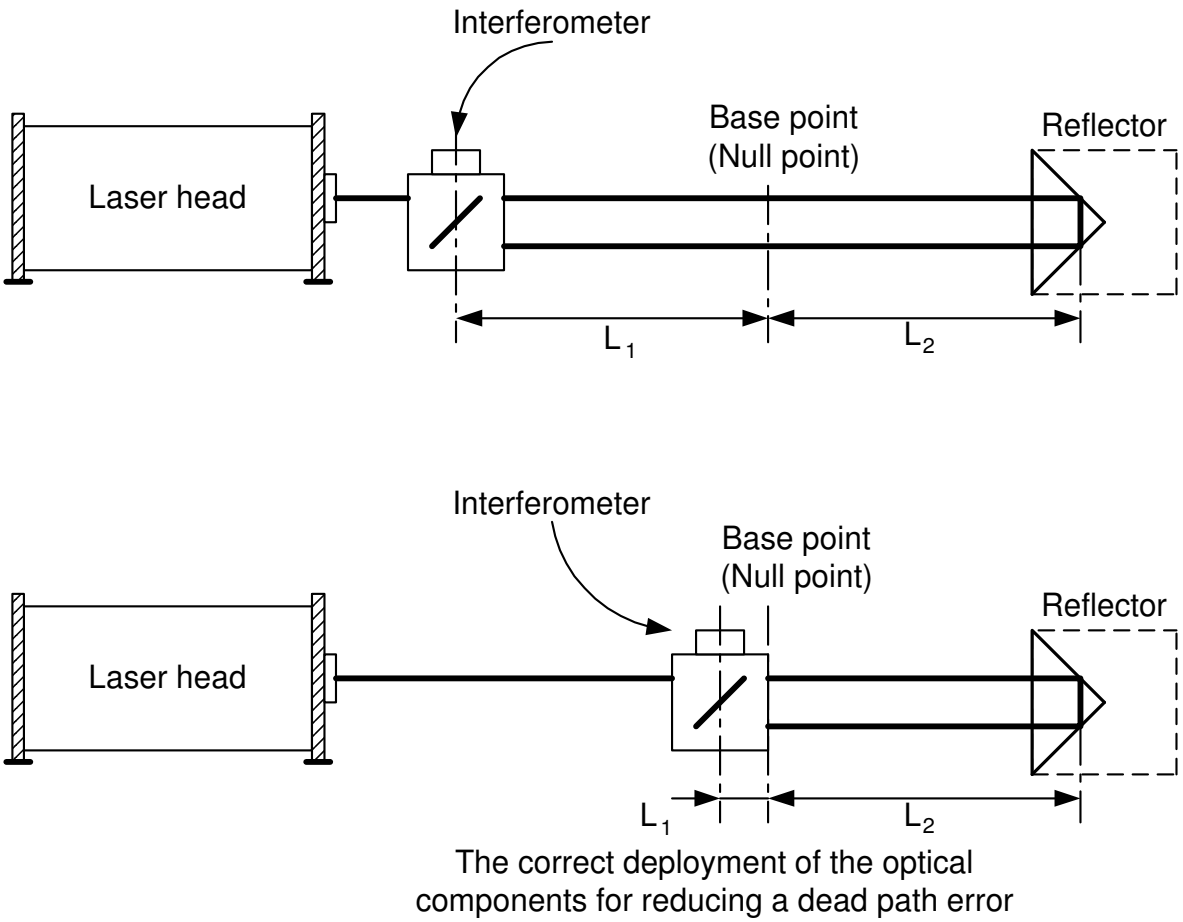


FIG.2.4. *AN ILLUSTRATION OF A DEAD PATH ERROR.（死路径误差举例说明）*

Cosine error

余弦误差

If the laser beam is not parallel to a measured axis of a machine (i.e. the optical path is not properly adjusted) then a difference between the real distance and the measured distance occurs. This error of misalignment is known as a cosine error, because its magnitude depends on the angle between the laser beam and the axis of the machine (fig. 2.5).

If, as a reflector a flat mirror is used, then the beam must be perpendicular to it. If the machine changes its position form point A to point B, then the beam stays perpendicular to the mirror, but moves on its surface. The distance measured by the laser interferometer L_{LMS}, will be smaller, than the real distance L_M, according to

如果激光束与一台机器的测轴不平行（即光路调整不正确）,那么现实之间的距离和测量距离的差异发生。这种偏差错误被称为余弦误差，因为它的大小取决于激光束和机器轴的角度（图 2.5）。如果平面镜用做反射镜，激光束必须垂直于它。如果机器的位置从 A 点移动到 B 点，那么光束保持垂直于镜子，但在其表面移动。由激光干涉仪测得的距离 L_{LMS},比真正的距离 L_M 小，根据下列公式：

$$L_{LMS} = L_M * \cos\Theta \qquad (6)$$

The above equation is valid also when as a reflector a corner cube is used.

当角形反射器用做反射镜时，上述方程也是有效的。

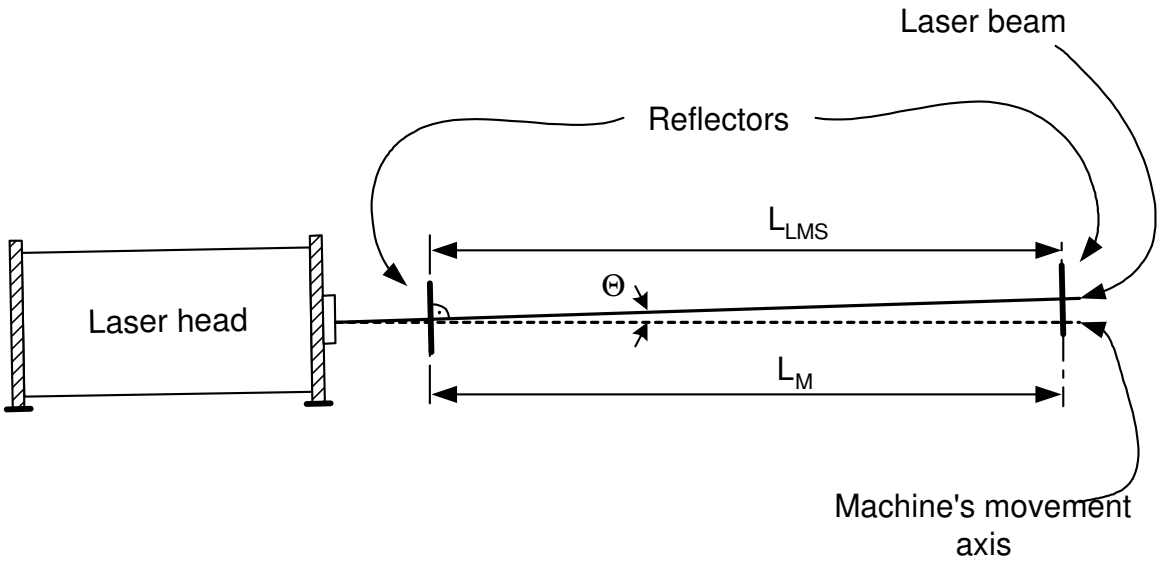


FIG.2.5. *THE BEAM UNADJUSTMENT AS A CAUSE OF A COSINE ERROR.（余弦误差的一个原因是光束不调适）*

The only method of eliminating the cosine error is a proper laser beam adjustment procedure performed before the measurement.

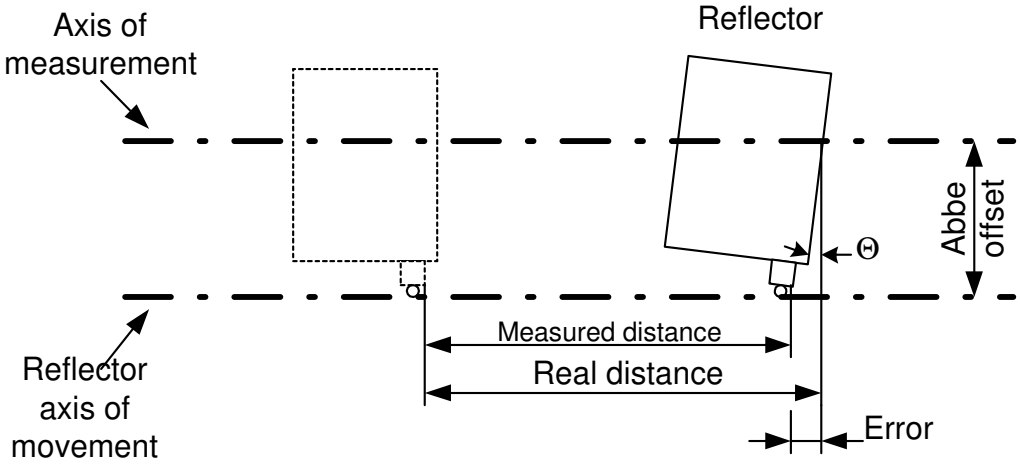
消除余弦误差唯一的方法是测量之前有一个适当的激光束调适程序。

Abbe error

阿贝误差

An Abbe error occurs when, during measurements, the measured part does not move perfectly parallel with the axis of the measuring system. The sloping of the reflector is the greater the longer is the distance between the axis of the measurement and the axis of movement. This distance is called *An Abbe offset*. Only the movements in the axis of the measurement are important (see fig. 2.6). An Abbe error may be avoided only when there are no angular movements of the retro-reflector in the axis of the measurements.

在测量中，阿贝误差出现，当所测的部分不完美的随测量系统的轴平行移动时。反射的倾斜越大，测量轴和运动轴的距离越长。这个距离称为阿贝抵消。只有测量轴的运动才是重要的（见图 2.6）。一个阿贝误差



可能避免，只有在测量轴上没有反射器的角度运动时.

FIG.2.6. *AN ILLUSTRATION OF AN ABBE ERROR.（阿贝误差的举例说明）*

Laser stability error

激光稳定性误差

As was already mentioned, in laser measurements the laser wavelength instability changes directly the readout from the interferometer, e.g. a relative instability of the laser in the range of 1ppm (10^{-6}), causes an error of 1μm on every 1m of a measured distance. Therefore the laser instability error is important mainly in measurements in vacuum (where a refraction coefficient is constant) and when a low stability laser is used (e.g. a semiconductor laser). The stability of usually used in laser measurement systems, HeNe gas lasers is 0.02 ppm, so the stability error may be neglected.

正如已经提到的，在激光测量中，激光波长不稳定性直接改变从干涉仪读出的结果，例如，一个在 1ppm 的范围（10^{-6}）激光相对不稳定性，对每一个测量距离 1 m 造成 1μm 错误。因此，激光不稳定性误差主要在真空测量中（其中折射系数为常数）以及当较低稳定性激光使用时（如半导体激光器）是很重要的。通常使用的激光测量系统，氦氖气体激光器的稳定性是 0.02 ppm，因此稳定性误差是可以忽略的。

Other errors

其他误差

In some conditions, a noticeable error may be caused by the electronic part of the interferometer. As the electronics is used mainly for counting, the errors may be associated either with miscounting (some pulses are not counted) or with miscalculating (the calculations are made with finite precision).

在某些情况下，一个明显的误差可能是由干涉仪电子零件造成的。由于电子产品是主要用于计算，这些错误可能是与算错（有些脉冲不计算在内）或错误估计（计算在有限精度内）相关。

Summary of laser measurement system errors

激光测量系统误差综述

In order to show which of the errors influence the accuracy of a laser measurement system the most, an exemplary calculation of errors on a 1m long steel machine is shown on figures 2.7 and 2.8. Different scales of the charts should be taken into account.

为了表述哪些误差最影响激光测量系统，图 2.7 和 2.8 显示的是在一个长 1m 的钢机上的误差模拟计算，应考虑到图表不同的尺度。

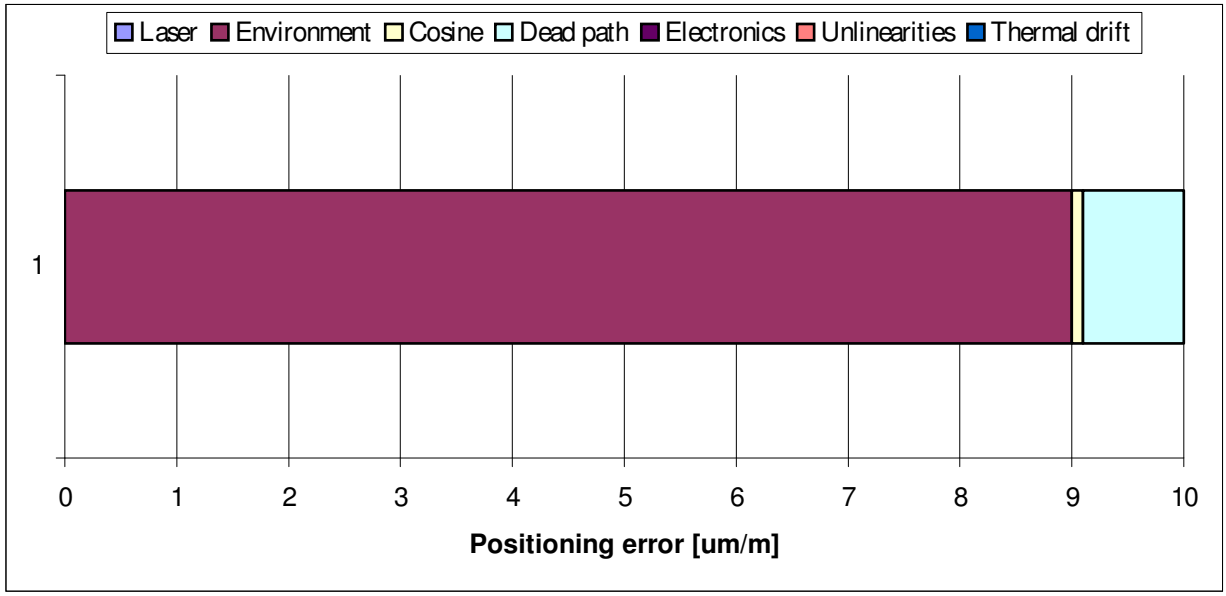


FIG.2.7. *A CALCULATION OF ERRORS FOR A LASER MEASUREMENT SYSTEM* ***WITHOUT THE COMPENSATION*** *OF THE ENVIRONMENT.*

(无环境补偿的激光测量系统的误差计算)

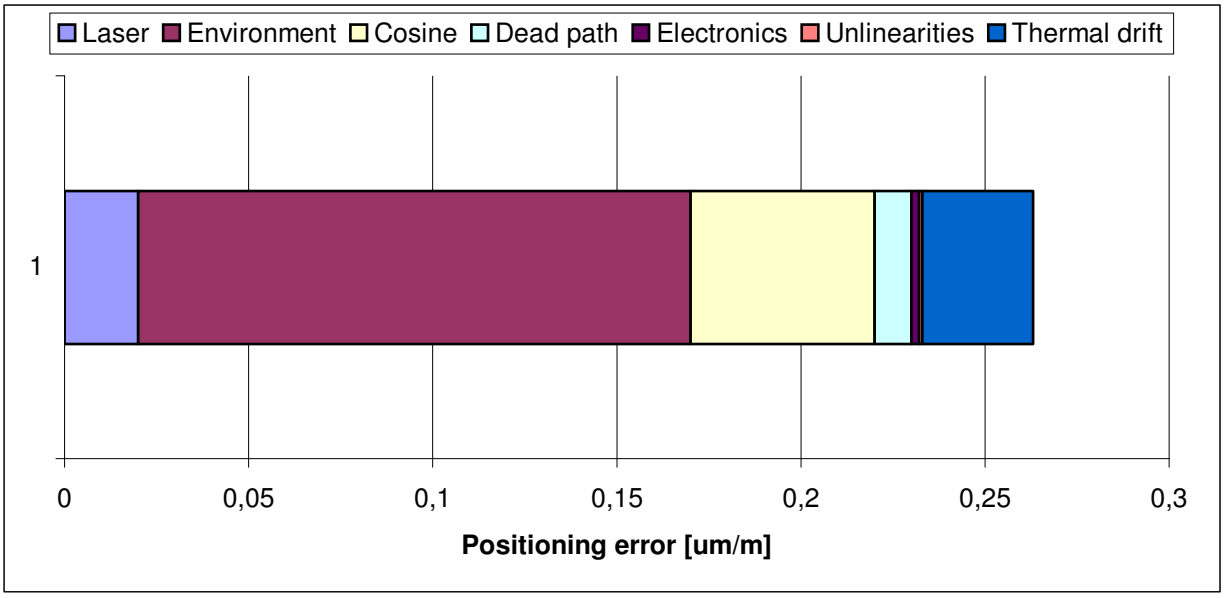


FIG.2.8. *A CALCULATION OF ERRORS FOR A LASER MEASUREMENT SYSTEM **WITH THE COMPENSATION** OF THE ENVIRONMENT.*

(有环境补偿的激光测量系统的误差计算)

3

PREPARATION

准备过程

To start the measurements using the Laser Interferometer ***LP30-3D***, software *"LP 30 -3D"* should be installed on HDD of a PC computer. The hardware requirements are:

- Windows 9x/NT/2k/XP operating system,
- CR-ROM
- Pentium processor, 90 MHz or better
- SVGA graphic card with minimum resolution 800x600.

要用 LP30-3D 激光干涉仪开始测量，软件“LP30-3D”应安装在一台 PC 计算机的硬盘中。硬件要求如下：

- Windows 9x/NT/2k/XP 操作系统，
- 光盘
- 奔腾处理器，90 MHz 或更高
- SVGA 图形卡，最低分辨率 800 * 600。

Software installation

软件安装

To install the LP program on the PC computer put the CD disc " LP30-3D " into the CD-ROM. The program will be installed automatically.

要把 LP30 程序安装到个人计算机上，只需把“ LP30-CD”光盘放到 CD - ROM 驱动器中，该程序将会自动安装。

Components of the Laser Interferometer

激光干涉仪部件

The number of required components depends on the type of measurement to be performed. Standard set (for **linear measurements**) includes:

1. 1 x Laser head – *Laser Interferometer*
2. 1 x Power supply - *Laser Interferometer Power Supply*
3. 1 x Tripod stand
4. 1 x Environmental Compensation Unit - (ECU) **SM1**
5. 1 x Laser head to power supply cable
6. 2 x Magnetic holder **UM1**
7. 1 x Linear interferometer **IL1**
8. 1 x Linear retro-reflector **RL1**
9. 3 x Basis temperature sensor **T1, T2, T3**
10. 1 x RS232C cable
11. 1 x Manual Strobe cable (to trigger measurements remotely)

See fig. 3.1 on the next page for pictures of the elements of the standard set.

所需的部件数量取决于测量类型。标准套件（线性测量）包括：

1. 1 个激光头 - 激光干涉仪
2. 1 个电源 - 激光干涉仪电源
3. 1 个三脚架支架
4. 1 个环境补偿组件 - （ECU）SM1
5. 1 个电源线的激光头
6. 2 个磁性支架 UM1
7. 1 个线性干涉仪 IL1
8. 1 个线性反射器 RL1

9. 3 个基础温度传感器 T1，T2，T3

10. 1 个 RS232C 接口电缆

11. 1 个手动频闪灯电缆线（可遥控测量）

见下页图 3.1 标准套件的组成部分的图片.

Additional elements for angular measurements are:

角度测量的附加部件包括：

1. 1 x Angular interferometer **IK1**
2. 1 x Angular retro-reflector **RK1**
3. 2 x Beam directing mirror **ZK1**
4. 1 x Rotary table **SO1**

1. 1 个角度干涉仪 IK1

2. 1 个角度反射器 RK1

3. 2 个光束反射镜 ZK1

4. 1 个转盘 SO1

Fig.3.1. The elements of the standard set（标准套件的组成部分）

4

OPERATION

运行

Preparing the interferometer to work

干涉仪的工作准备

The Laser Interferometer ***LP30-3D*** is supplied from autonomous power supply – "*Laser Interferometer Power Supply"*, connected via USB to the PC.

Before starting the measurements place the laser head –*"Laser Interferometer"* on the **Tripod** stand and connect it with the LP power supply. Connect cable from laser head to socket on the front panel of the *"Laser Interferometer Power Supply"*. Connect the USB cable to the front panel of the Power Supply and to the PC/Notebook.

Connect the Environmental Compensation Unit - (ECU) (TPH) to 6-pin marked METEO socket on front panel of the Power Supply. Temperature sensors T1, T2, T3 connect to 4-pin sockets placed on the front panel. To 6-pin socket marked STROBE should be connected a source of strobe signal. Strobe signal may be produced by a pulse switcher (5 m cable with a pulse switcher is in standard set) or by any other devices. Strobe input is used to trigger the measurement manually or automatically.

LP30 – 3D 激光干涉仪是自动电源供应 – “激光干涉仪电源”，通过 USB 连接到 PC。

在进行测量之前，把“激光干涉仪” 的激光头安装在三脚架的支架上，并连接电源。连接从激光头到插座面板上的“激光干涉仪电源”电缆。将 USB 电缆连接到电源的前面板以及电脑/笔记本电脑上。

连接环境补偿组件 - （ECU）（TPH）到电源前面板的 6 孔插座。温度传感器 T1，T2，T3 分别连接到前面板上的 4 孔插座。6 孔插座的频闪灯应连接到闪光灯信号源。频闪信号可能由一个脉冲切换器（标准套件中，5m 电缆带一个脉冲切换器）或由任何其他设备产生。闪光灯输入是用于手动或自动触发测量。

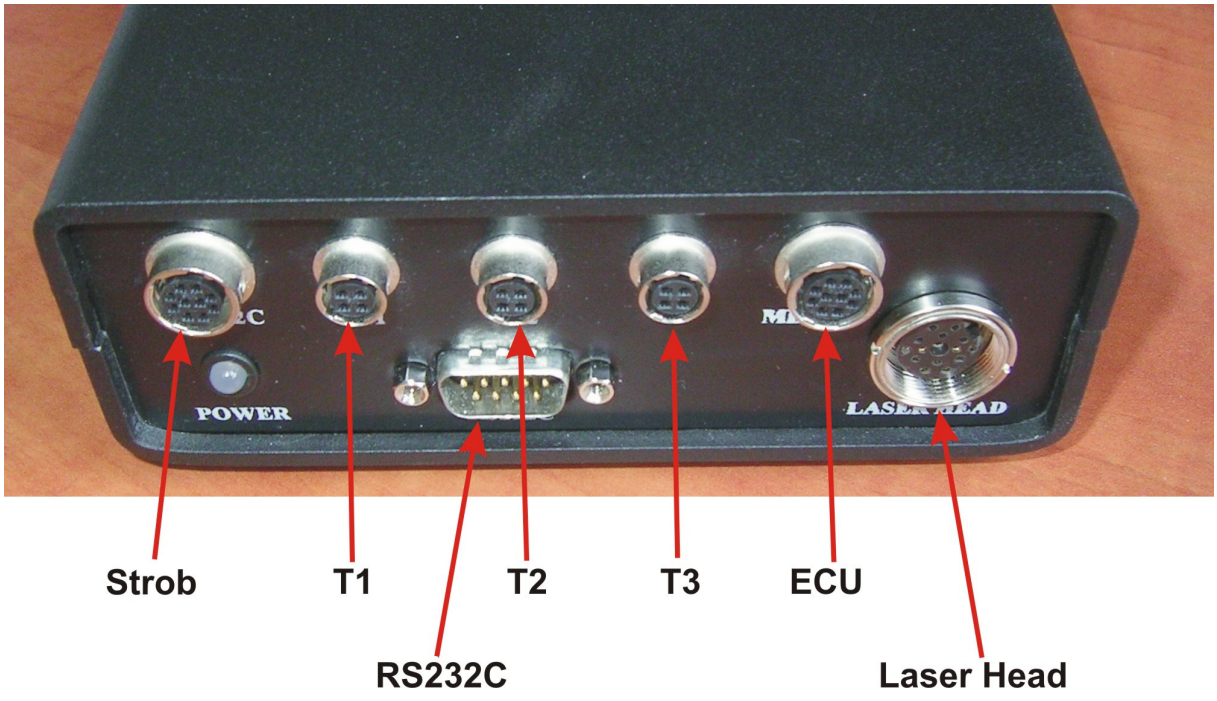


FIG.4.1. ELECTRIC CONNECTIONS OF THE LP30-3D （LP30 激光干涉仪的电连接图）

Turning the system on

打开系统

Switch on the device according to the following instructions:

1) Switch on the power switch on the Laser Interferometer Power Supply,

2) Start LP30 program on a computer.

When the main menu appears at the computer monitor (fig.4.2) choose option **Display** (fig.4.4)

按照以下说明打开设备开关：

1）打开激光干涉仪电源开关，

2）启动计算机上的 LP30 程序。

当主菜单出现在电脑显示器上时（图 4.2），选择选项 **Display 展示**（图 4.4）.

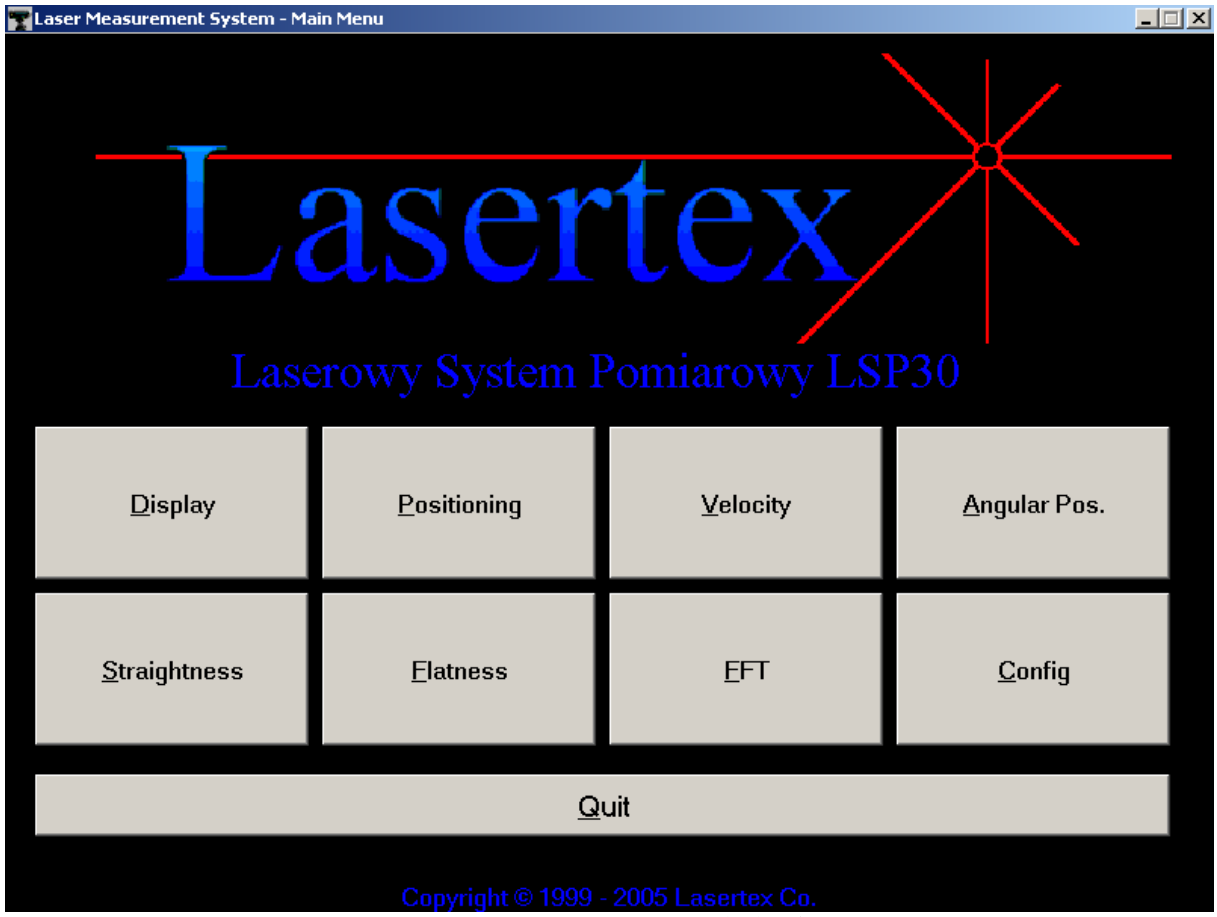


FIG.4.2. MAIN MENU（主菜单）

If the program is started before the Power Supply is turned on, or the Power Supply is not connected properly to the computer, on the monitor an error window with *"No connection or Power Supply Off"* line will appear (fig. 4.3). In this case close the program, check the connection and/or the supply of the Interferometer (POWER diode on) and restart the program.

如果该程序在启动电源之前打开，或者电源没有正确连接到计算机，显示器会出现“无连接或关闭电源”的错误窗口（图 4.3）。在这种情况下关闭该程序，检查连接和电源，重新启动该程序。

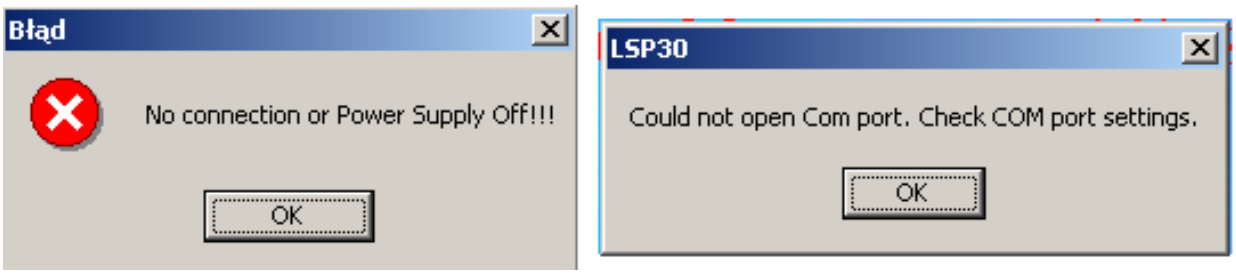


FIG.4.3. ERRORS THAT MAY OCCUR DURING SOFTWARE LOADING

（软件加载过程中可能出现的错误）

If the Interferometer is connected to the wrong COM (in case serial port is used instead of USB) then an error window with *"Could not open COM port. Check COM port settings"* line will appear. To change the number of used COM port choose option **Config** (fig 4.4).

如果干涉仪连接到错误的 COM（万一串行端口代替 USB 接口），那么错误窗口“无法打开 COM 端口，请检查 COM 端口设置”将会出现。要更改所使用的 COM 端口号，选择选项 **Config 配置**（图 4.4）。

Getting basic information from the system

从系统中获取基本信息

After proper software loading choose option **Display**. The laser system will be preheated. The **beam intensity** – the green indicator on the screen – will appear and disappear. The speed of changes will become smaller due to the increase in the temperature of the laser system cover. The measuring system is ready for an adjustment of the optical arrangement of the laser path.

软件加载后，选择选项 **Display 显示**。激光系统将预热。光束强度 – 在屏幕上的绿色指示灯 – 将出现和消失。变化的速度将越来越小，随着激光系统表面的温度升高。该测量系统也适用于激光路径光学安排调整。

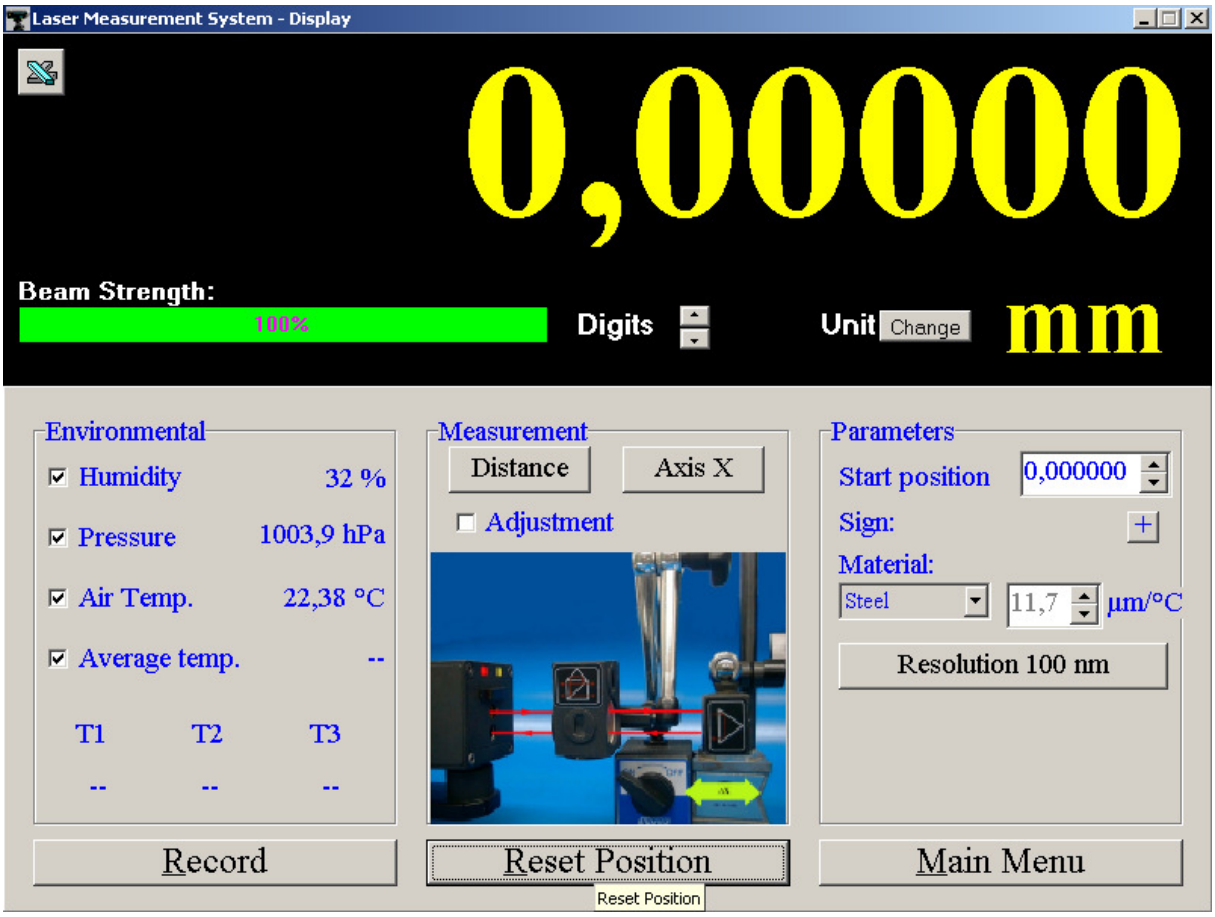


FIG.4.4. OPTION DISPLAY（展示选项）

On the Display screen there are four panels:

- Panel containing the digital result of the measurement, the measuring signal level indicator and the buttons for changing the number of displayed **Digits** and for changing **Units**. Quantity of significant digits on display may be changed with the use of buttons ↑ ↓, pressing button with an inscription **Change** changes measurement unit on the display. In the upper left corner there is an icon making link to Microsoft Excel (if installed). Running this link allows to register measurement in Excel cells by each STROBE button press.

在显示屏幕上有四个控制板：

- 控制板，包含测量数字结果，测量信号水平指示灯以及改变显示位数和单位的按钮。有效数字显示数量可能随按钮↑↓的使用而改变，按 Change 按钮会改变显示屏的测量单位。在左上角有一个图标，可链接到

Microsoft Excel（如果已安装的话）。运行此链接就可以在 Excel 单元格登记每次按频闪按钮的测量结果。

- Panel **Environmental** where measuring data obtained from the Environmental Compensation Unit - (ECU) are shown. On the screen there are shown: temperature, pressure and humidity of the atmosphere and temperatures measured by three base temperature sensors. Average temperature of the base measured by three sensors is also presented.

-环境控制板，显示环境补偿套件（ECU）获得的测量数据。在屏幕上显示有：温度，压力，大气湿度以及三个基础温度传感器测出的温度。三个基础温度传感器测出的平均温度也有显示。

- The **Measurement windows** shows basic information about the performed measurement. With the left button the type of measurement can be changed. The right is used for choosing measuring axis. At every changing of measuring option (i.e. distance, speed, angle, straightness) and changing of measuring axis (i.e. X, Y, Z) a picture shows how to setup the optical elements. Click with the left mouse key on the picture to get detailed information on how to setup the optical elements (help online).

-测量窗口，显示正在进行的测量的基本信息。测量类型可随左边的按钮改变。右边是用于测量轴选择。在每一个测量选项改变（即距离，速度，角度，直线度）和测量轴改变（即 x，Y，Z 轴）时，图片会显示如何安装光学元件。单击图片中鼠标左键获得如何设置光学元件（帮助在线）的详细信息。

- Panel **Parameters**, contains a few options. Option **Sign** allows choosing whether enlarging distances between the retro-reflector and the interferometer gives positive (default “+”) or negative result on the display. In the option **Material** one can choose the material from which a basis of a machine is made of, the value of the thermal expandability coefficient of the basis is accepted for calculations of

compensation. Option **User** make it possible to enter any value of the thermal expandability coefficient. In the panel **Resolution** one can change between high (10nm) and low (100nm) system resolution. In higher resolution accepted movement velocity is strictly limited (see Technical data chapter for details). With the option **Environmental** the Environmental Compensation Unit - (ECU) may be switched on or off. From console of the computer one can switch off the external Environmental Compensation Unit - (ECU) and enter the parameters of atmosphere by hand.

-参数控制板，包含了一些选项。选项 **Sign** 允许选择是否扩大反射器和干涉仪的距离,从而给出正的或负的结果（默认“+”）。选项 **Material 材料**，可以从中选择机器的基础材料，这个热扩展性系数的数值在计算补偿时被接受。选项 **User 用户**可以输入任何热扩展性系数数值。在分辨率控制板，可以改变高达（10 纳米）和低至（100 纳米）的分辨率。在较高的分辨率中，可接受的运动速度受到严格限制（见技术数据章节）。按 **选项 Environmental** 可开启或关闭环境补偿套件-（ECU）。从计算机的控制台，可以关掉外部环境补偿套件-（ECU），手工进入环境参数。

When measurements are executed with automatic compensation of the atmosphere parameters and compensation of the basis temperatures (Environmental Compensation Unit - ECU switched on) one should:

- Place the Environmental Compensation Unit - (ECU) on the machine in the vicinity of the laser beam.
- Place the sensors of the basis temperature along the measured axis on the machine basis

Measurements executed without automatic compensation are referred to normal conditions: temperature 20 °C, pressure 1016 hPa, humidity 50 %.

当测量执行的是自动环境参数补偿和基础温度补偿（环境补偿套件-开启），应当：

- 将环境补偿套件-（ECU）放在机器上的激光束附近。
- 沿机器基础上的测量轴，放置基础温度传感器。

没有执行自动补偿的测量被称为正常条件：温度 20℃，压力 1016 hPa，湿度 50%.

Adjustment of the optical path

调整光路

An adjustment of the optical set up should be conducted in option **Display**. It can be done during laser head heating. Final check should be made when the system is ready to work.

The Laser Head should be firmly attached to the tripod. The tripod should not touch a machine as it may cause vibration of the laser head and the optical path. Turn special attention, not to move the legs of the tripod during the measurements, because it will cause shift of elements of the optical path and the necessity of repetition of the adjustment process. The arrangement of the tripod helps to adjust the optical path. Inspection of the level of arrangement can be made using level fastened on the tripod and on the laser head.

The diaphragm of the laser beam is found on the front panel of the laser head. The diaphragm can be placed in three positions:

- Right extreme position (fig. 4.5a) –" **Adjustment**" – the laser beam goes out through opening in the diaphragm about 2 mm diameter,
- Central (fig. 4.5b) –" **Measurement**" from the laser head goes out beam about 8 mm diameter,
- Left (fig. 4.5c) - extreme position, in which the exit of the beam from the laser head is completely closed.

光学设置调整应在选项 **Display 显示**进行。在激光头预热时，这可以做到。应在系统准备工作之前做最后检查。

激光头应该是稳固地附于三脚架。三脚架不应该接触机器，因为它可能会导致激光头的振动和光路的振动。特别注意，不要移动测量过程中的三脚架的支脚，因为这会造成光路要素的转移和重复调整的必要性。三脚架的安排有助于调整光路。检查安排的水平时，可使用三脚架和激光头固定的水平。

在激光头的前面板上发现了激光束的光圈。光圈可以放在三个位置：

- 右极端的位置（图 4.5a） - “调整” - 激光束通过光圈，直径约 2 毫米，
- 中环（图 4.5b） - “测量” 从激光头出光束，直径约 8 毫米，
- 左极端的位置（图 4.5c），激光头光束出口完全封闭。

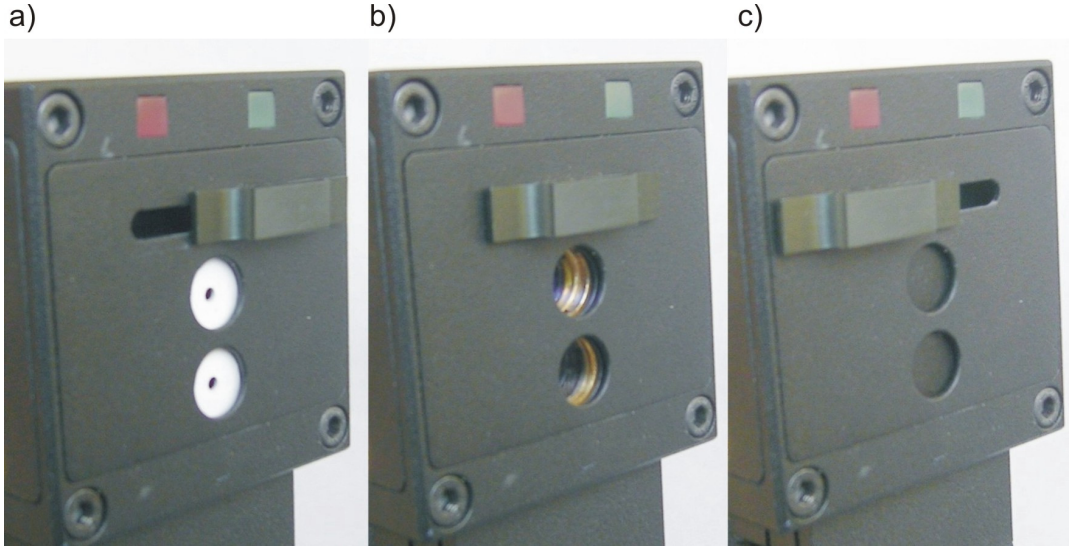


FIG.4.5. *DIAPHRAGM POSITIONS. A) RIGHT, B) CENTRAL, C) LEFT（光圈位置，右，中，左）*

During transportation or when system is not used, correct position of diaphragm is left extreme position. In this position optics is safe from getting dirty, covering with dust and accidental damage during transportation.

在运输过程中或在系统不使用时，光圈的正确位置是左极端的位置。在这个位置上光学元件是安全的，会防止弄脏，染上灰尘或者运输过程中的意外损坏。

Basic rules of an optical path adjustment:

光路调整的基本规则：

When the position of the laser beam is being corrected, the spot position on the diaphragm of the interferometer (the interferometer is placed closer to the laser head) – should be regulated with X stage and up-down translation stage Z and up-down translation of the tripod. The spot position on the retro-reflector diaphragm (the retro-reflector is far from laser interferometer) – should be regulated with "α" angle adjustment in vertical and "β" angle adjustment in horizontal line. The regulating elements of the laser head are presented in fig. 4.6. In Fig. 4.6 one can see the position of the laser head for Y axes measurement. In this position the function of the regulating elements will change.

当激光束的位置正受到纠正，在干涉仪的光圈上的点的位置（干涉仪应放在靠近激光头的位置）应调整 X 轴，并上下调节 Z 轴和上下调节三脚架。关于反射器光圈点的位置（反射器远离激光干涉仪） - 应纵向"α "角度调整和横向" β"角度调整。激光头的调节要素在图. 4.6. 图. 4.6 中，可以看到 Y 轴测量时激光头的位置。在这个位置上，调整元素的功能会发生变化。

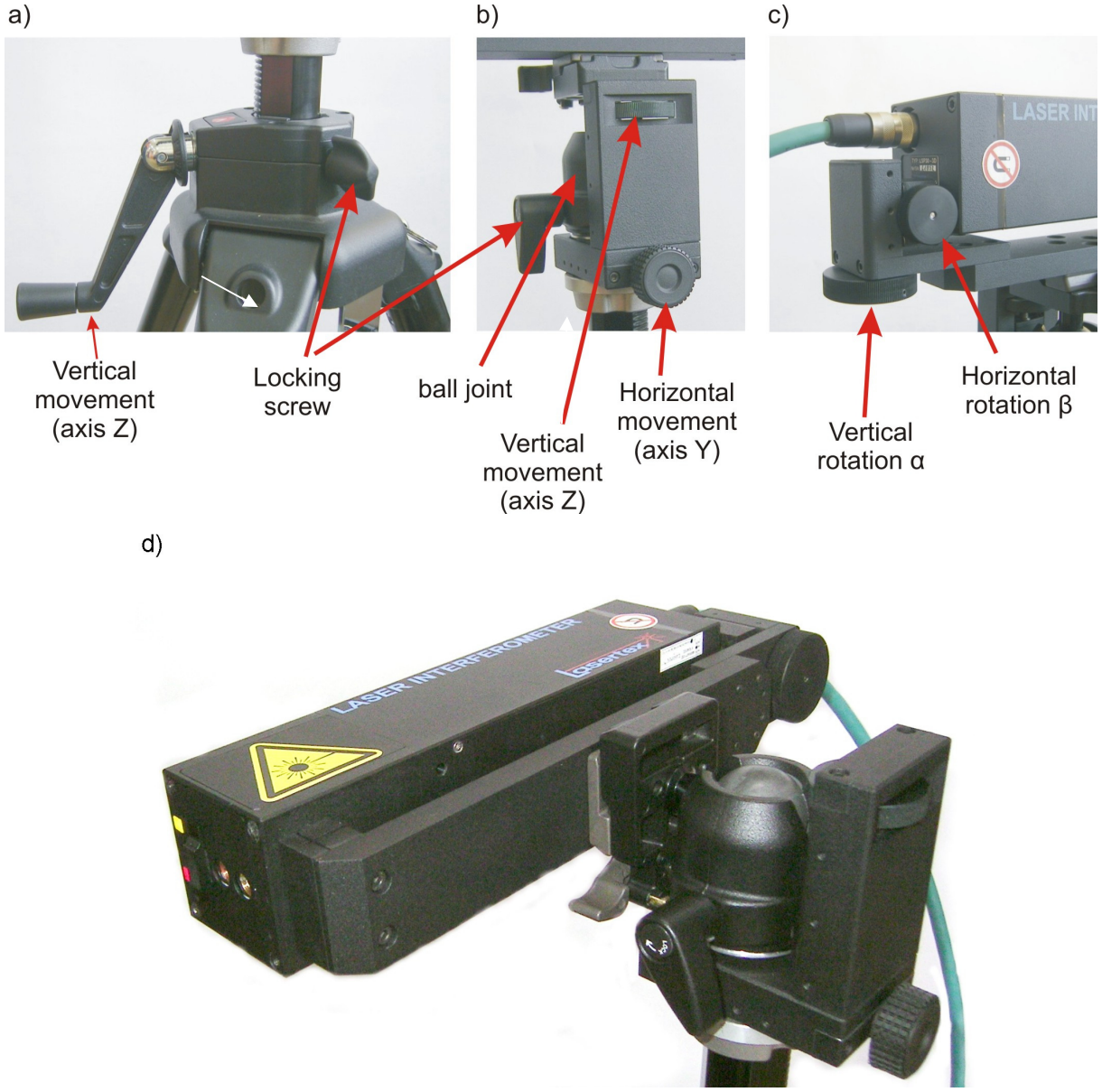


FIG.4.6. LASER HEAD ADJUSTMENT ELEMENTS.（激光头调整元素）

Adjustment process

调整过程

1. In the option **Display** in the PC program choose type of measurement, which will be done and axis along of which measurements will be carried. On the screen will appear a drawing showing recommended arrangement of measuring elements at the chosen type of measurement.

2 Linear interferometer IL1 and linear retro-reflector RL1 should be mounted on magnetic holders UM1, UM2. Regulating elements of the laser head should be placed in central positions, to assure maximum range of regulation.

3. Choose which from the optical elements will be moved (retro-reflector RL1 or interferometer IL1) and attach both with magnetic holders: one to a moving element of the machine, second to an element in relation to which displacement will be measured (for example: the retro-reflector may be fasten to a moving element, and the interferometer to a motionless table). Remember, *that relative linear displacement between the retro-reflector and the interferometer is measured*.

Attention! It is inadmissible to place one of optical elements (i.e. RL1 or IL1) outside the machine on an additional stand – the system measures then also displacements of the machine in relation to the stand.

4. The moving element of investigated axis should be moved in closest position to the laser head position

5. Place the interferometer optics **IL1** and the retro-reflector **RL1** on the axis of movement. Check the level indicator that the interferometer is in horizontal position.

Attach the retro-reflector **RL1** to the interferometer **IL1** (there is a special socket for this purpose in **IL1**) – see fig.4.7.

1. 在电脑程序选项 **Display** 中，选择测量类型，那么所选的将会完成，测量所沿的轴线也会显示。在屏幕上会出现一个图形，显示某种测量类型的测量元素的建议安排。

2. 线性干涉仪 IL1 和线性反射器 RL1 应安装在磁支架 UM1，UM2 上。激光头的调整元素应放在中心位置，以确保调整的最大范围。

3. 选择哪些光学元件将被移动（反射器 RL1 或干涉仪 IL1），并都附在磁支架上：一至机器的运动元素，二至测量位移有关的元素（例如：反射器可固定在一个移动的元素，干涉仪固定在静止的桌子上）。记住，反射器和干涉仪之间的相对的线性位移被测量。

注意！不允许机器以外的任何光学元件在（即 RL1 或 IL1）别的支架上 – 那样的话系统会测量机器到支架的位移。

4.调查轴的移动元素应在最接近激光头的位置移动。

5.将干涉仪光学原件 IL1 和反射器 RL11 放在运动轴上。检查水平指标确保干涉仪是在水平位置。 把反射器 RL1 附到干涉仪 IL1 上（为此目的，有一个 IL1 专用插座）见图 .4.7 。

FIG.4.7. START POSITION OF ADJUSTMENT（调整的起始位置）

6. Move the moving element of the machine together with the attached optical element in opposite extreme position. Diaphragms on **IL1** and **RL1** and of laser head place in position – "Adjustment".

6. 移动机器的运动元素与附加的光学元件到相反的极端位置。IL1 和 RL1 光圈和激光头的地方在 "调整"。

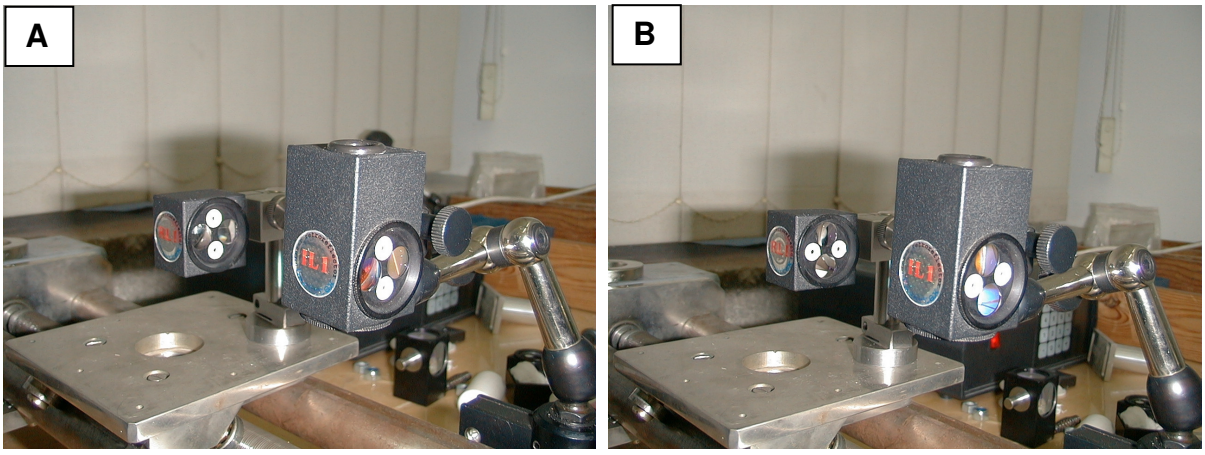


FIG.4.8. ADJUSTMENT POSITION (A) AND WORK POSITION (B)

调整位置（a）和工作位置（B）

7. Regulate the tripod height and level of the laser head by means of a sphere joint. The laser beam has to fall on upper hole in interferometer diaphragm and after passage by the hole must be found within diaphragm area of the retro-reflector. The laser head should be placed horizontally (for horizontal axes) – control it on the level indicator.

7. 调节三脚架的高度和激光头的水平，通过一个球形节点。激光束必须落在干涉光圈的洞上层，通过后必须在反射器的光圈领域内找到它。激光头应水平放置（横向轴），控制水平的指标。

8. Using regulating elements of the laser head find a position in which laser beam passes through both upper apertures in the diaphragms placed on the interferometer and the retro-reflector.

8. 使用激光头的规范元素，找到一个位置，使激光束既通过干涉仪又通过反射器光圈的上部的孔。

9. Switch the diaphragms on **IL1** and **RL1** in a position of work.

9. 打开 IL1 和 RL1 光圈，到工作位置。

10. Using the regulating elements of the laser head adjust the position of laser beams on the diaphragm of laser head. Two return beams should exactly cover each other an entrance hole on the front panel of the laser head. If this is necessary gently correct the position of the **IL1**. Shift the diaphragm on the laser head to the position "Work". The level of the measuring signal (the green indicator on the screen of the computer) should have value not less than 80 % during translocation of the moving element along the whole path.

10. 使用激光头的调节因素调整激光头光圈上激光束的位置。两次的返回光束应互相完全涵盖激光头的前面板入口处的洞。如果必要的话，可轻轻地调整 IL1 的位置。转移激光头的光圈到“工作”位置。测量信号电平（计算机屏幕上的绿色指示灯）应具有不低于 80%的价值，在沿整个路径移动元素易位时。

11. For precision adjustment, when the straightness measurement will be carried on, use electronic adjustments. Switch screen of the display to Adjustment mode. Using adjustment screw set two crosses blue and green to the centre of the screen. Blue cross corresponds to reference beam while the green one to measuring beam see Fig 4.9.

11.直线度测量将进行时需要精密调整，使用电子调整。切换 **Display 显示** 屏幕到调整模式。使用调整螺丝设置两个十字架，蓝色和绿色的，到屏幕的中心。蓝十字架对应参照光束，绿十字架对应测量光束。 见图 4.9

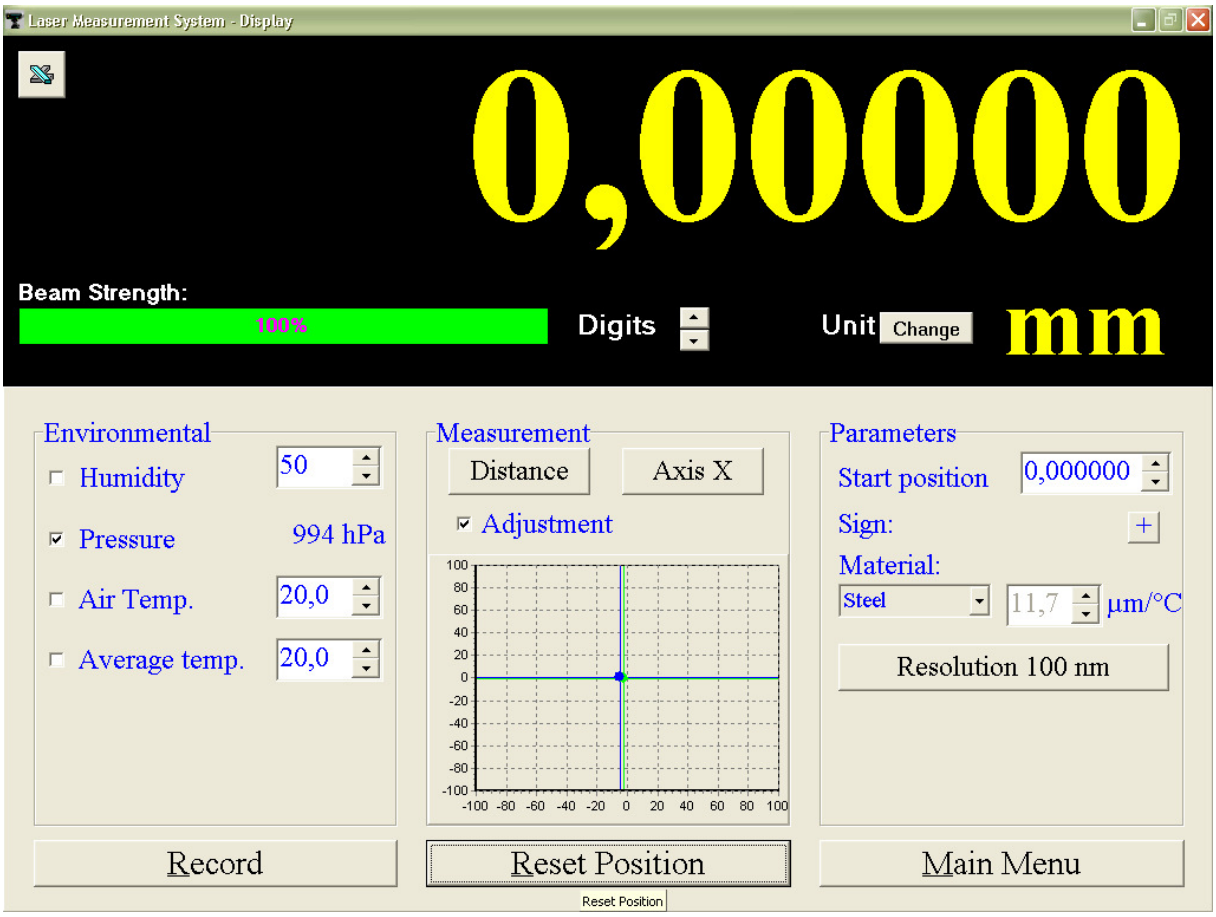


FIG.4.9.CORRECT ADJUSTMENT OF OPTICAL PATH

（正确调整光路）

12. Reset displayed position using “Reset” button on the display. System is ready to work.

12 . 使用显示器上的“重置”按钮重置显示位置。系统就开始工作了。

Attention! Remember, that the position when the interferometer touches the retro-reflector can serve only to adjust. Be sure that during measurements in extreme nearest measuring position the retro-reflector does not touch the interferometer, because it can be a source of measuring errors.

注意！请记住，干涉仪触及反射器的位置只可以用于调整。必须保证，测量中，极端接近的测量位置，反射器不能触摸干涉仪，因为这可能是一个测量误差的来源。

5

LINEAR MEASUREMENTS

线性测量

Measurement set

测量设置

Linear measurements are the most often used measuring option. Using this option it is possible to measure:

- Linear displacement;
- Velocity of moving element;
- Linear positioning.
- Vibrations (see Chapter 8);

Measurements may be executed in three mutually perpendicular measuring axes X, Y, Z. Change of a measured axis will demand displacements of optics.

线性测量是最常用的测量方案。使用此方法可测量：

- 直线位移;
- 运动元素的速度;
- 线性定位。
- 振动（见第八章）;

测量可能在三个互相垂直的测量轴 X，Y，Z 中进行，测量轴的变化需要光学元件的位移。

Required measuring set: a computer, a laser head with a power supply, a stand Tripod, two magnetic holders **UM1** (or two **UM2**), a Environmental Compensation Unit (ECU) - **SM1**, sensors of basis temperature **T1**, **T2**, **T3**, a linear interferometer **IL1**, a linear retro-reflector **RL1,** remote control Strobe (option).

所需的测量设置：一台计算机，一个带电源的激光头，一个三脚架支架，两个磁性支架 UM1（或两个 UM2），环境补偿套件（ECU） SM1，基础温度传感器 T1，T2，T3， 一个线性干涉仪 IL1，一个线性反射器 RL1，遥控频闪灯（可选）。

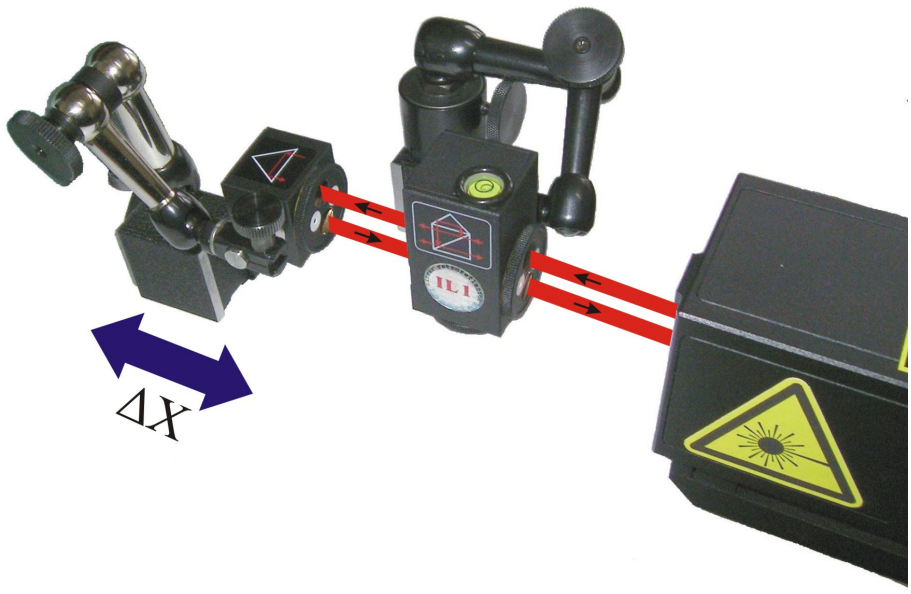


FIG.5.1 SET UP FOR LINEAR MEASUREMENTS IN X AXIS.

（设立线性测量 X 轴）

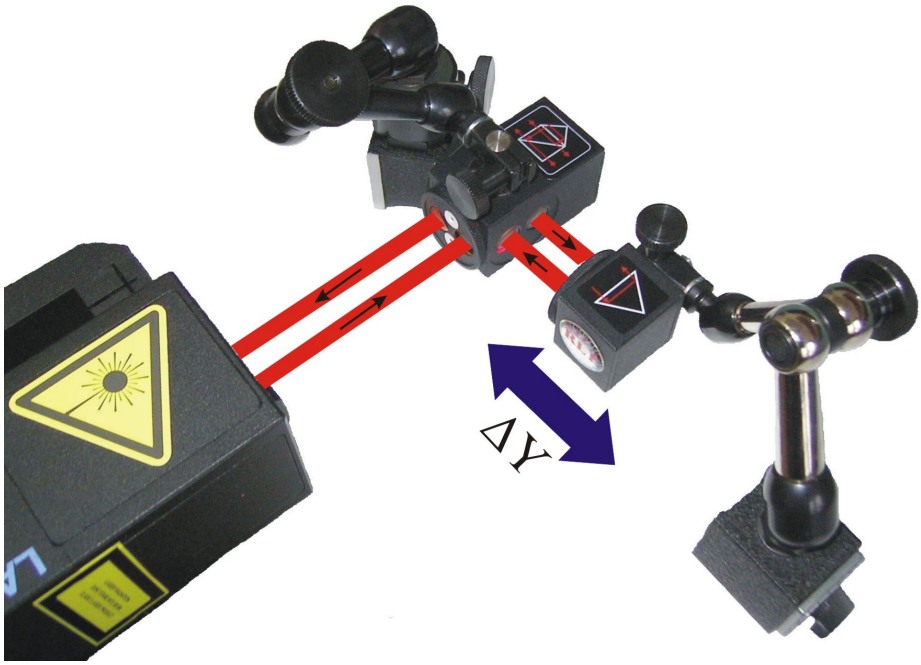


FIG.5.2. SET UP FOR LINEAR MEASUREMENTS IN Y AXIS.

（设立线性测量 Y 轴）

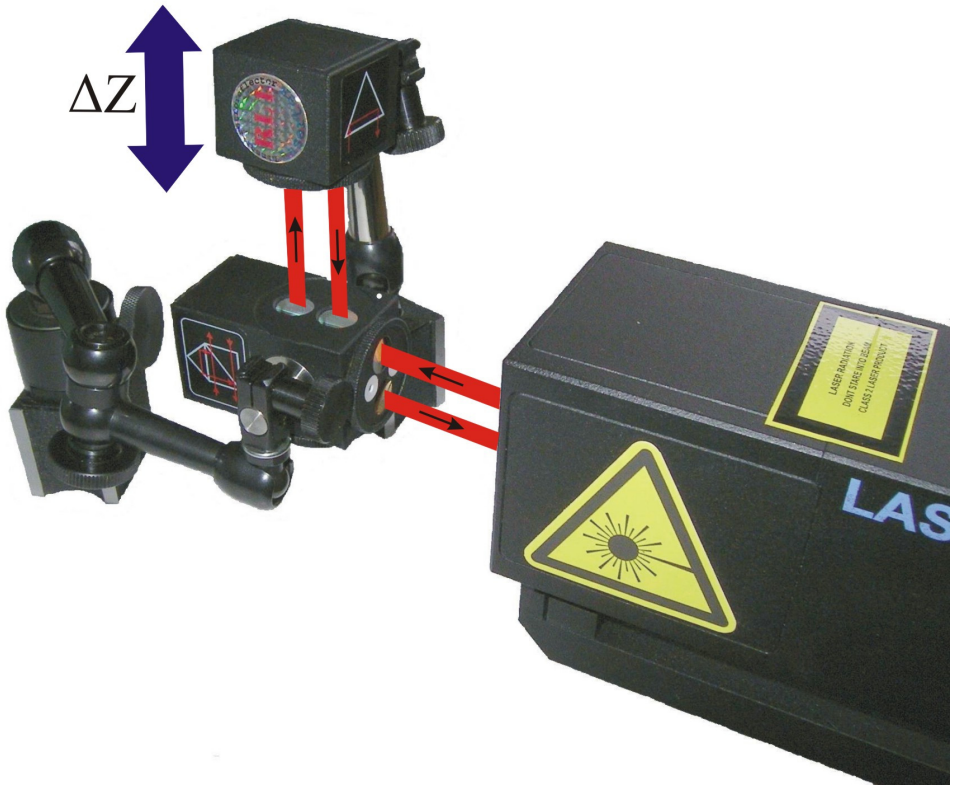


FIG.5.3. SET UP FOR LINEAR MEASUREMENTS IN Z AXIS.

（设立线性测量 Z 轴）

Linear displacement measurement

线性位移测量

When one want to prepare the measurement system for the measurement of a linear displacement electric connections and adjustment of the optical path (see chapter 4) must be carried out. When the laser system is ready to work – green LED light on the forehead of the laser head. Next it is necessary to check optical path, i.e. whether the measuring signal reached at least 80% on the entire axis. The measurements now can start. A measuring unit (mm, µm), a number of significant positions on a display, a measured axis, a sign (“+” or “-“) and base’s material may be chosen. After resetting, the display system is ready for measurements. When the retro-reflector is moved on the screen the displacement in relation to a starting point is displayed (it is also possible to move the interferometer in relation to the standing retro-reflector).

当测量系统准备线性位移的测量时，电线连接和光路调整（见第 4 章）必须进行。当激光系统准备就绪时，激光头前额显示绿色的 LED 灯。下一步，有必要检查光路，即查看，测量的信号是否达到了整个轴的至少 80%。这些之后，测量可以开始。一个测量单位（毫米，微米），一个显示器上有效地位置，测量轴，一个符号（“+”或“ - ”）和基本的物质要选好。重置后，这显示系统就可以测量了。当反射器在屏幕上移动，与起点相对的位移就显示出来（也可以移动干涉仪，相对于站立的反射器）。

Linear displacement velocity measurement

直线位移速度测量

The arrangement of the optical path and the laser head should be the same as in the paragraph above. The measurement of the linear displacement velocity is

executed in option **Display**. The type of measurement should be changed on **Velocity** and a unit should be chosen (**m/min, m/s**). After resetting the result on the display, system is ready to the velocity of displacement measurement. During translocation of the retro-reflector the value of velocity is presented on the screen (is possible to measure velocity moving the interferometer in relation to motionless the retro-reflector).

该光路安排和激光头应该是与上段相同。该线性位移速度测量是通过选项**显示**执行的。测量类型应改为速度，单位应选择（米/分，米/秒）。重置显示屏上的结果后，系统就可以开始位移速度测量。在反射器易位的过程中，速度值在屏幕上显示（也可以进行速度测量，通过移动干涉仪，反射器保持静止）。

Velocity graph

速度图

The arrangement of the optical path and the laser head should be the same as in the paragraph above. It should be activated **Main Menu** and chosen option **Velocity**. Than a button **Start** should be pressed and the object, which displacement velocity we investigate, should be moved. After moving stop button **Stop** should be pressed. On the screen will appear a graph of velocity. Clicking on a part of the graph and moving the mouse rightward we receive increasing of a selected fragment of the graph. Clicking on a part of the graph and moving mouse leftward we cancel increasing. The graph can be printed or saved to file when we choose from upper menu **File**, and then suitable option (i.e. Save, Save as, Print).

该光路安排和激光头应该是和上段相同。它应该被主菜单激活，并选择选项**速度**。然后按一个按钮，我们研究位移速度的对象，就会开始移动了。移动停止后要按**停止**按钮。在屏幕上会出现一个速度图。点击这个图表的一部分，向右移动鼠标，我们收到了图所选部分的增加。点击这个图表的

一部分，向左移动鼠标，我们取消增加。该图可以打印或保存到文件夹，我们要从上边菜单**文件**选择，然后选择合适选项（即保存，另存为，打印）。

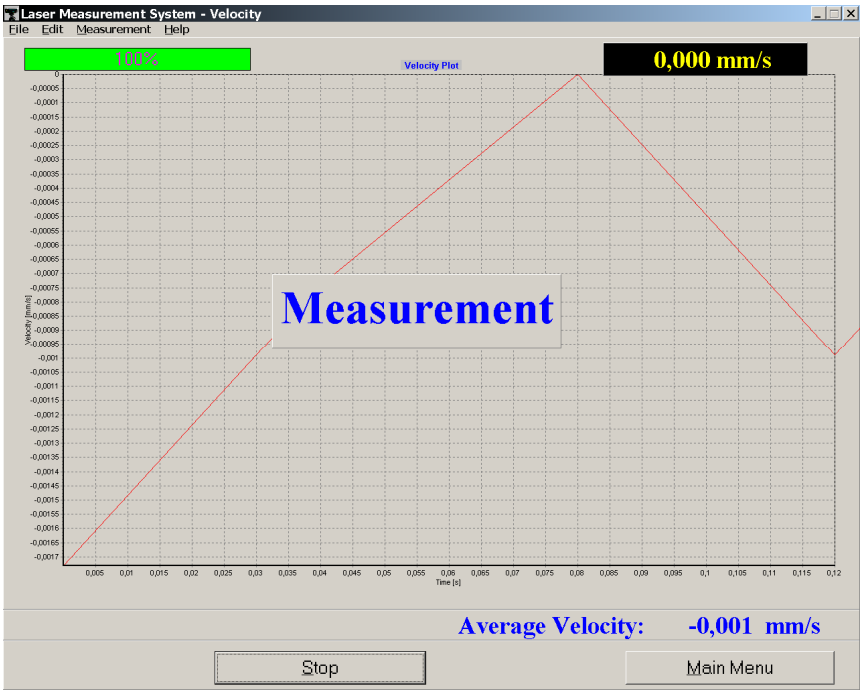


FIG.5.4. VELOCITY GRAPH WINDOW (速度图窗口)

An example graph of changes of the linear displacement velocity of a machine table in one axis is presented on fig. 5.5.

一台机器在一个轴线上的线性位移速度的变化举例图表， 见图表 5.5 。

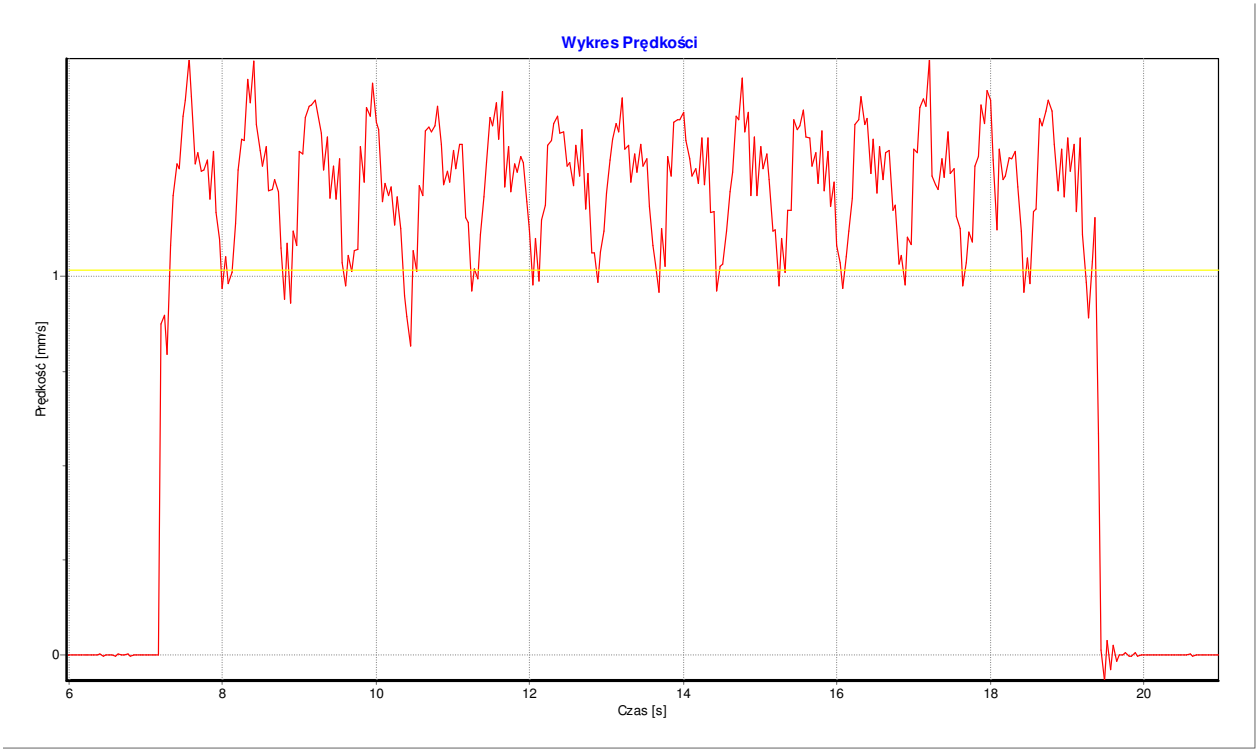


FIG.5.5 EXAMPLE GRAPH OF CHANGES OF LINEAR DISPLACEMENT VELOCITY.

（线性位移速度变化举例图表）

Program also counts an average velocity from a visible range on the graph. Possible is also presetting of minimum and maximum values for measured axis. Clicking left mouse button on selected axis or clicking right mouse button within the area of the graph appears a menu, from which we choose proper axis. On the screen appears a window of scaling of axes **Velocity scale** and **Time scale**. We can place scaling automatic or set maximum or minimum values.

Program makes possible also saving the velocity graph and then loading it for example to Word editor. To save graph to file we should click with right mouse key within the area of the graph. Popup menu will appear menu from which we should choose **Copy to clipboard** instruction.

The choice of the speed unit is also possible: from menu **Edit** we should choose option **Config** , where we can set the velocity unit.

程序还计算图上可见范围内的平均速度。测量轴的最低和最高值也可以显示。点击所选轴鼠标左键或单击选定图表区域的鼠标右键，会出现

一个菜单，从中我们选择适当的轴。在屏幕上显示速度和时间缩放比例轴的窗口。我们可以自动地缩放或设置最高或最低值。

程序也可以保存速度图，然后加载到，比如，Word 编辑器。要保存图形到文件夹，我们应该在图形区域点击鼠标右键。弹出菜单中会出现新菜单，从中我们应该选择复制到剪贴板指令。

速度单位也是可以选择的，从菜单**编辑**，选择选项**配置**，在这里我们可以设置速度单位。

Linear positioning measurement

线性定位测量

The linear positioning measurement is the most advanced option of linear measurements. It is most common form of measurement performed on the machines. The system measure linear positioning accuracy, repeatability and backlash by comparing the position displayed on a machine's readout with the true position measured by the interferometer. In order to start measurements option **Main Menu** should be activated and **Positioning** should be chosen. On the screen will appear a window **linear positioning** as presented on fig. 5.6

线性定位测量是线性测量最高级的方式。这是最常见的机器上的测量形式。该系统测量线性定位精度，重复性以及通过比较机器的读数显示与干涉仪的测量的真正位置的反弹。为了开始测量，选项**主菜单**应被激活，并应选择**定位**。在屏幕上会出现一个**线性定位**窗口。见图 5.6

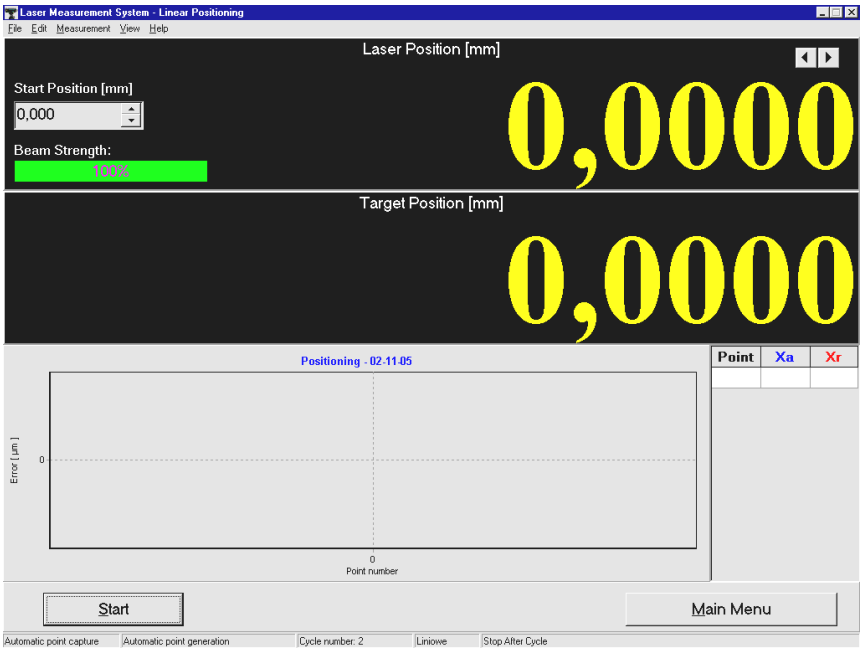


FIG.5.6 LINEAR POSITIONING WINDOW.

（线性定位窗口）

In this window appears upper menu, which consists of options: File, Edit, Measurement, View, Help. In option File are found instructions making possible reading measuring data from disc, saving data on disc and printout of measurements results. Option Edit allows to enter measured machine parameters, preview of measurement results in every cycle of positioning and an edition of positioning points (when option Target Points from List from menu Measurement is active).

在这个窗口出现上部菜单，选项包括：文件，编辑，测量，视图，帮助。在**文件**选项中，可以找到从光盘读取数据，保存光盘数据和打印测量结果的指令。选项**编辑**允许输入所测机器的参数，每一个周期定位的测量结果预览和定位点版本（当测量菜单中的选项**目标点**处于激活状态）。

Option **Measurement** includes the options connected with the process of measurement:

Start – beginning of measurements

Stop – break of measurements

Dynamic – choosing this option activates dynamic mode of linear positioning measurement.

Manual Capture – choosing this option causes, that for measuring points we can get measured value of displacement by pressing a button **Manual Capture** or by pressing pulse switcher of Strobe. If this option is not active points are captured automatically (program detects the moment of machine stop).

Target Points From List – after choosing this option on the screen appears a window for edition measuring points in which we write or count distance value for positioning points. If this option is not active then the positioning points are marked automatically in first measuring cycle.

Stop After Cycle – if this option is active program breaks the measurement after realization of a measuring cycle and if it is not active number of cycles set in configuration is executed.

Change Given Values – setting this option gives possibility to change an earlier defined distance value of a measuring point during the measurement process. Before point capture appears a window in which can be written new distance value whereupon marked are only places after comma what causes that it is not necessary to write all distances.

选项**测量**包括与测量过程相关的选项：

开始 – 开始测量

停止 – 暂停测量

动态 – 选择此选项激活线性定位测量的动态模式。

手动捕获 – 选择此选项的原因，为了测量点，我们可以得到位移测量值，通过按**手动捕获**按钮或按频闪灯脉冲开关。如果这个选项未激活，点会自动获取（程序检测机器停止的时刻）。

列表目标点 – 在屏幕上选择这个选项后，会出现一个窗口，可编辑我们写入的或统计的定位点距离值的测量点。如果这个选项未激活，那么定位点会在第一测量周期被自动标记。

循环后停止 – 如果此选项处于激活状态，程序会在完成测量周期后中断，如果这个选项未激活，配置的周期设置在执行。

变化给定值 – 设置这个选项可以改变测量过程中的之前定义的测量点的距离值。捕获点前出现一个窗口，其中可以编写新的距离值，即只有逗号后的地方被标记，没有必要写入所有的距离。

Option **View** serves to switching on or off a panel **Target Position, Error Table** and to switching on drawing on the graph of measuring points from all cycles (active cycle is drawn using solid line but remaining cycles are illustrated using only points).

选项**查看**可以打开或关闭**目标位置**控制板和误差表，也可以打开所有周期测量点的图（活跃周期是用实线画的，但其余周期只使用点来表示）。

If system is ready to work, then on the screen appear two digital displays and gauge of measuring signal level. On the upper display measured value is shown, on the bottom display value of target position, which is read from data points table or appointed automatically. Under the displays from the left side there is presented a graph on which the results of measurements are shown. From the right side **Error Table** is found. Under the graph button **Start** - beginning measurement and button **Main Menu** - allowing to enter to Main menu are placed.

如果系统可以工作的话，在屏幕上会出现两个数字显示器和信号电平的测量仪。在上显示器，测量值显示；在下显示器，目标位置值显示，该值是从数据表读取或自动指定的。在显示器下边左侧，显示一份测量结果图形。误差表在右侧。图下边，有**开始**按钮，开始测量；和**主菜单**按钮，允许进入主菜单。

In the bottom parts of the window a status bar can be found, on which there is presented a configuration of the positioning measurements. In the first field

information about method of measuring points capture is found (manual, automatic). In second field information whether measuring points originate from list or are marked automatically is shown. The next field informs about number of cycles in series (number of cycles executed one after one, if not active is option **Stop** after every cycle). In the last field information about activity of option **Stop** after every cycle is presented.

状态栏在在窗口底部，显示定位测量配置。第一区域显示测量点采集方法的信息（手动，自动）。第二区域显示关于测量点是否来自名单或自动标记的信息。下一个区域显示一系列周期数（一个接一个执行的周期数，如果未激活，是每个周期后停止）。最后一个区域显示有关每周期后的选项**停止的**活动信息。

To execute the linear positioning measurement program has to know the target position in which it has to make measurement and to count deviation. These can be automatically defined in the first measuring cycle on a condition that distances between points are marked with accuracy to full millimetre. The positioning points can be also written or counted after marking an option **Target Points From List**. After activating this option the positioning points can be defined in any accuracy.

要执行线性定位测量，程序必须知道目标位置，其中它必须做出测量和计算偏差。这些可以在第一个测量周期自动定义，在点与点之间的距离都精确到毫米的条件下。定位点也可被记下或计算，在标记选项**列表目标点**之后。激活选项后，这些定位点可以在任何准确度内定义。

Measurement can be driven in an **Automatic** option or in a **Manual Capture** option. In automatic version the system oneself recognizes the moment of stop, the value of target point, the direction of movement and the number of series.

For correct work of automatic option below rules should be used:

1) Time of stop duration in measuring point - at least 1 second,

2) Vibrations of machine - not too large.

测量可以在自动选项或手动捕获选项驱动。在自动版本，系统自己认出停止的时刻，目标点的价值，运动方向和序列号。

对于自动选项的正确工作，下面的规则应该使用：

1）测量点时的停止持续时间 - 至少 1 秒钟，

2）机器振动 - 不要太大。

If vibrations are too large – system does not capture points – then the option **Manual Capture** should be switched on in the menu **Measurement**. After choosing the **Manual Capture** option on the bottom of the screen appears an additional button **Manual Capture**. Capture of the measuring point takes place by pressing this button or pressing the button on the impulse switch.

如果振动过大 – 系统就不会记录点 – 那么**测量**菜单上的选项**手动捕获**应该打开。在选择**手动捕获**选项后，屏幕底部出现另外的**手动捕获**按钮。捕获测量点需要按这个按钮或按脉冲开关的按钮。

Examination of linear positioning of machine consists of at least 2 measuring cycles. In every cycle the measured machine will move the retro-reflector for programmed distance fore (Avers) and back (Revers). After each shift the machine should stop for a time at least one second. The measured distance by the laser system is saved in the table of results. After at least two series of measuring cycles, statistical calculations can be executed and execute-report from examination is prepared. In order to get the final report press a button **Report**. Using buttons **Remove** and **Add** it is possible to change the measuring cycle in which accidental error is suspected. The screen of the computer after pressing the button **Report** is presented on fig. 5.7

机器线性定位检查分为至少 2 个测量循环。在每个周期，测量机将按程序设定的距离，前后移动反射器。在每次转换后，机器应该至少停留一秒钟。该激光系统的测量距离被保存在结果表。至少有两个系列的测量周期之后，统计计算可以执行，然后检查执行报告就生成了。要获得最终报告，按**报告**按钮。使用按钮**删除和添加**改变测量周期，若怀疑其出现偶然误差。按下**报告**按钮后，计算机屏幕显示如图. 5.7。

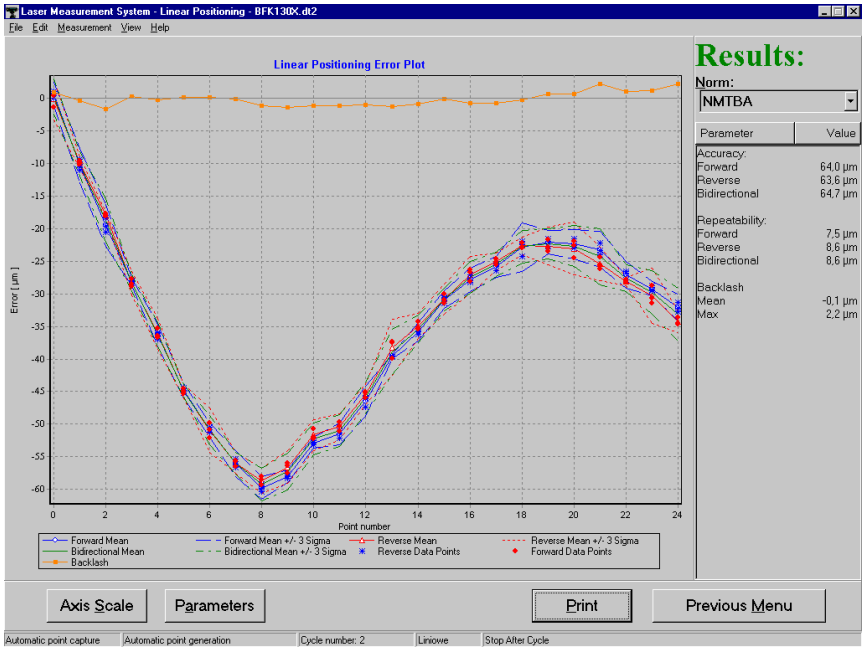


FIG.5.7. LINEAR POSITIONING RESULTS (线形定位结果)

The positioning parameters are presented on the graph. In the right side panel **Results** is found, on which results of statistical calculations and a norm according to which calculations were executed are presented. The norm can be chosen from a list. After choosing a new norm the results are recalculated.

定位参数在图表上显示。**结果**在右侧控制板呈现，其中，统计计算结果和做出此计算的参考标准都显示出来。标准可以从列表中选择。在选择一个新的标准后，结果会被重新计算。

Under the graph buttons used for the change of the axis scale **Axis Scale** (automatic scaling or assignment, minimum and maximum values), choosing of parameters shown on the graph **Parameters**, report, printout **Print** and return to looking through the measuring **cycles Previous Menu** are found.

Example of linear positioning report of CNC machine in axis is presented on fig. 5.8

在该图下面，有：用于改变轴的缩放比例的按钮（自动缩放或安排，最低和最高值），选择图表参数按钮，报告按钮，打印输出按钮，和返回到看一级菜单的按钮。

数控机床的轴的线性定位报告显示如图 5.8。

POSITIONING RAPPORT

Machine: BFK130 Serial No: Axis X

File Name: BFK130X1.dt2

Acquisition date:01-11-08 15:41:14 Current date: 02-11-06 15:08:15

Measurement System: LSP-30 Compact LASERTEX

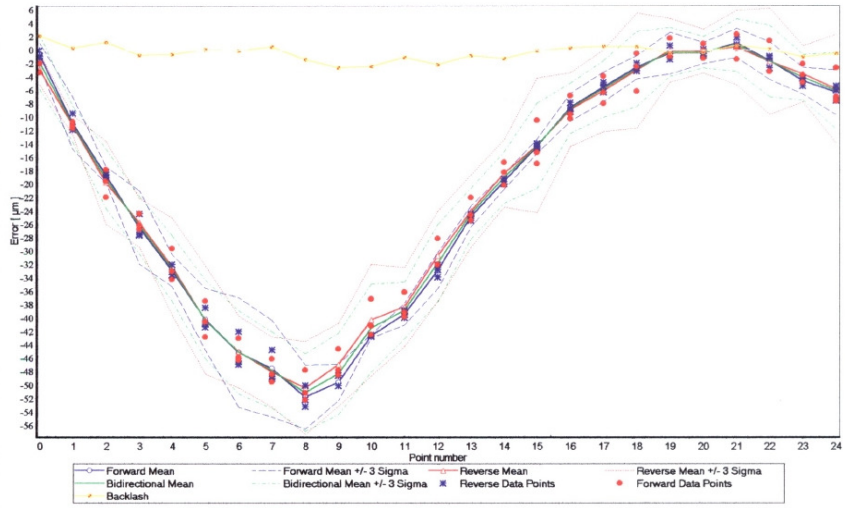
Results

Norm: NMTBA

Accuracy:	
Forward	59,8 µm
Reverse	63,5 µm
Bidirectional	61,5 µm
Repeatability:	
Forward	16,4 µm
Reverse	20,1 µm
Bidirectional	13,2 µm
Backlash	
Mean	-0,4 µm
Max	2,6 µm

Measurement Conditions

Air Temperature :	23,3 °C
Material Temperature :	19,4 °C
Humidity :	36 %
Pressure :	980 hPa



Comments:

Location: a **Operator:** sambor **Signature:**

FIG.5.8 LINEAR POSITIONING REPORT

（线性定位报告）

Recording mode

录音模式

The long term changes of the length of machine axes under changes of temperature condition may give the information about thermal properties of the machine. This kind of measurements called “Recording mode” may be chosen by pressing RECORD button on the **Display** screen. This switches the system into the mode of the data recorder. The time interval of the records could be programmed from the computer by setting a required value.

在温度变化条件下，该机器轴长度的长期变化可能会产生有关机器热性能的信息。这种名叫“录音模式”的测量通过按**显示**屏上的录音按钮可以选择。这会切换系统到数据录音模式。录音的时间间隔可以从计算机程序设置所需的值。

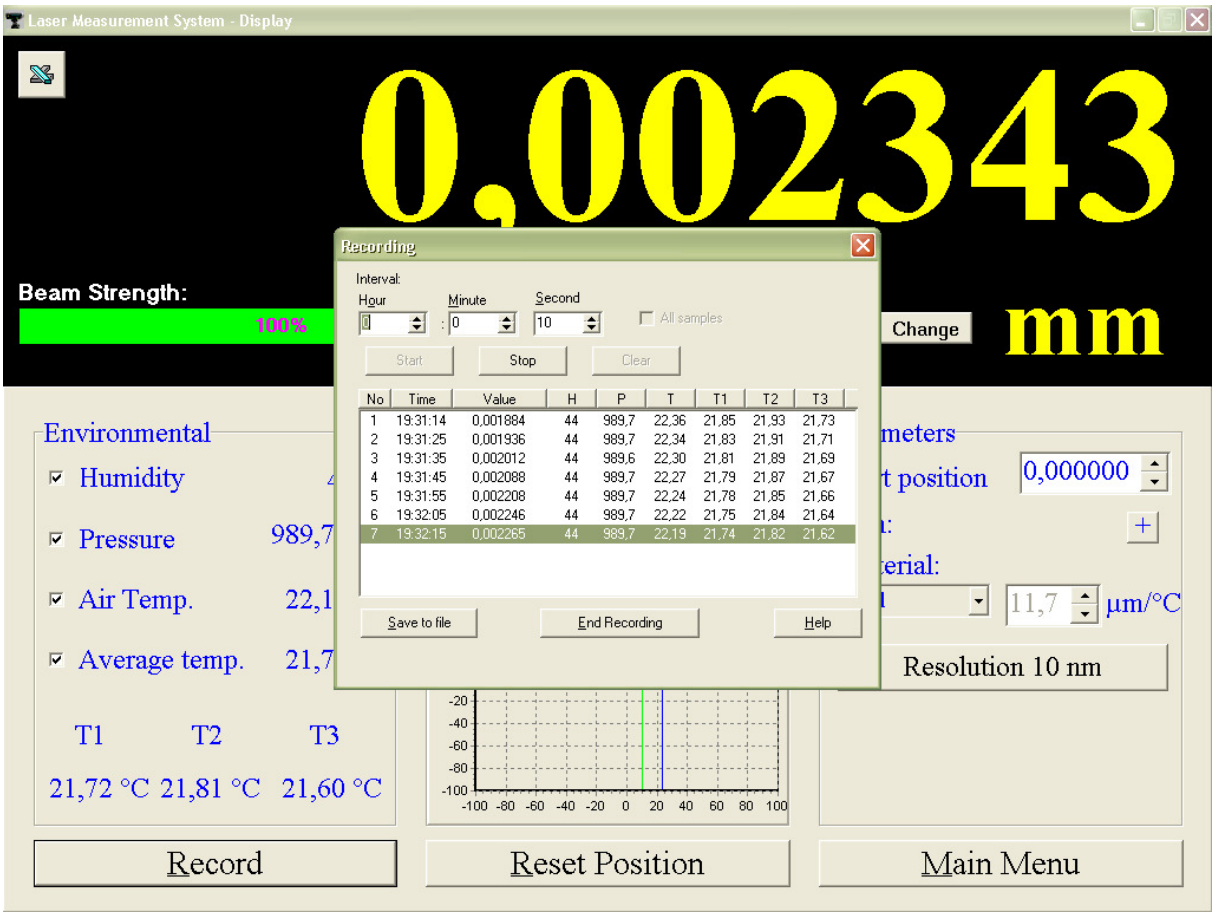


FIG.5.9 *RECORDING DATA MODE.*

（数据录音模式）

Pressing “End Recording” finishes the data recording. The results can be saved with the choice of “Save to file”. In fig. 5.9 the example of Data Record is presented.

按“录制完成”完成数据录音。结果可以选择 “保存到文件” 。图. 5.9 显示数据录音的例子。

6

ANGULAR MEASUREMENTS

角度测量

Measuring set for angular measurements

角度测量的测量设置

The angular measurements performed by the laser interferometer system are used for straightness, surface flatness and angular positioning of rotary tables. Straightness measurements can be done in three mutually perpendicular axes X, Y, Z.

由激光干涉仪系统执行的角度测量用于直线度，表面平面度和转台角度定位。直线度测量可以在三个互相垂直的 X，Y，Z 轴完成。

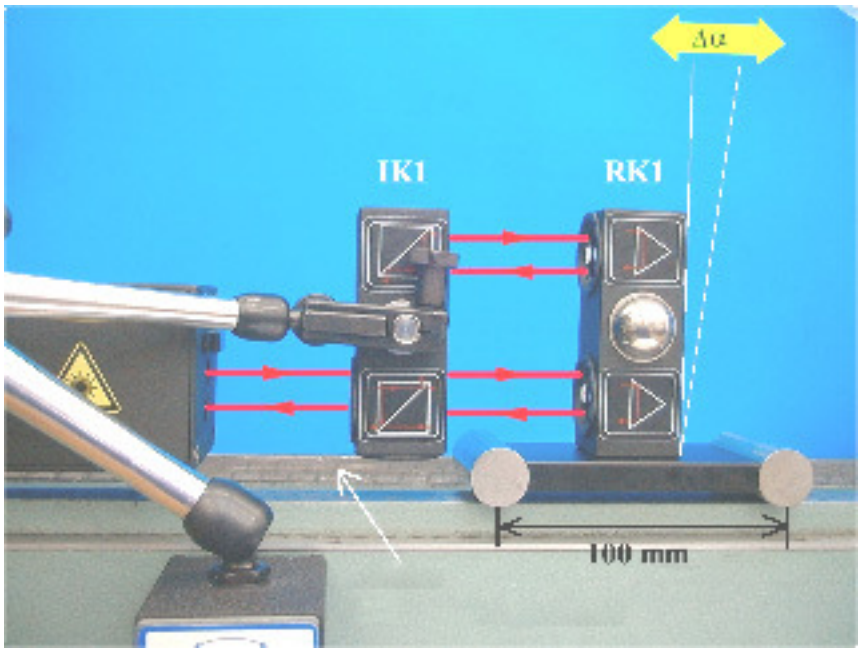


FIG.6.1. SETUP FOR ANGULAR MEASUREMENTS IN X-AXIS.

（X 轴角度测量设置）

Change of measuring axis will demand displacements of angular optics (figures 6.1, 6.2 and 6.3)

测量轴的变化需要角度光学原件的位移（图 6.1， 6.2 和 6.3 ）

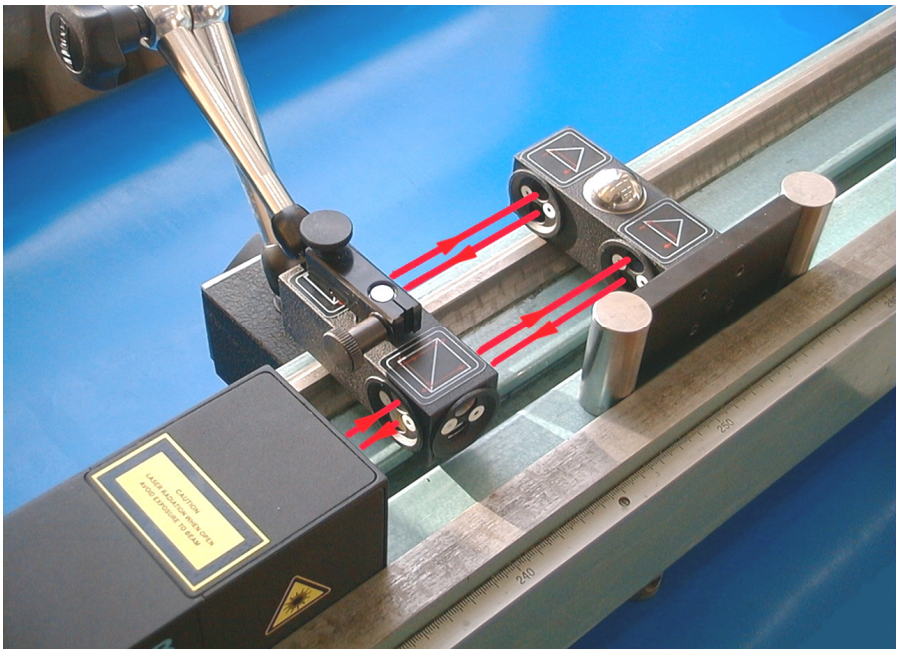


FIG.6.2. SETUP FOR ANGULAR MEASUREMENTS IN Y-AXIS.

（Y 轴角度测量设置）

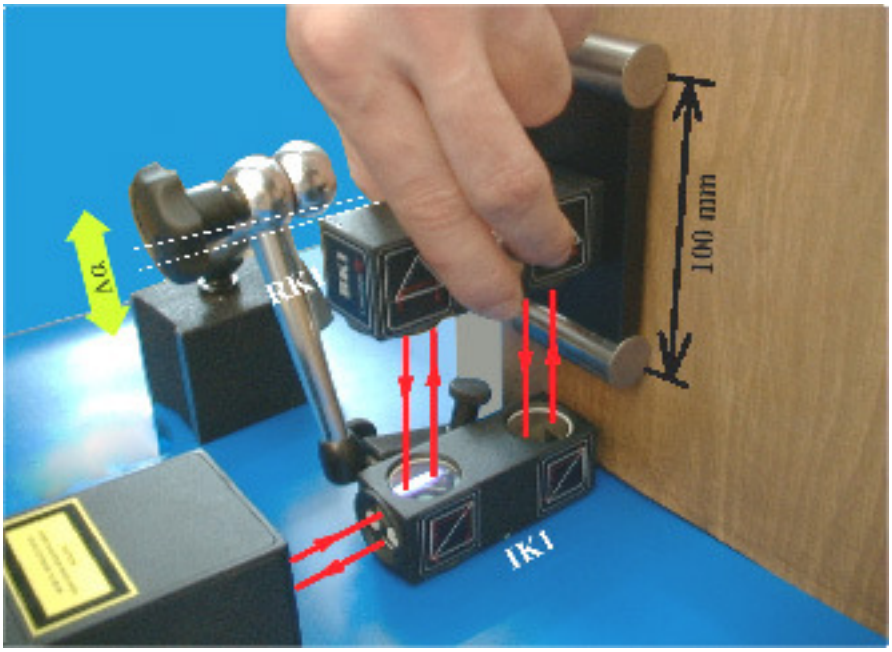


FIG.6.3. SETUP FOR ANGULAR MEASUREMENTS IN Z-AXIS.

（Z 轴角度测量设置）

Required measuring set: a computer, a laser head with an interferometer power supply, a stand Tripod, two magnetic holders **UM**1 (or **UM**2), a Environmental Compensation Unit - (ECU) **SM1**, sensors of basis **temperature T1, T2, T3**, an angular interferometer **IK1**, angular retro-reflector **RK1** mounted on **P100** mm base, remote control Strobe (option).

Auxiliary equipment used in the angular measurements is: two mirrors ZK1 mounted on supports, serving to reflect the laser beam - necessary to measurements of the surface flatness; a rotary table **SO1** controlled by step motor - used to angular positioning measurements.

所需的测量设置：一台电脑，一个带干涉仪电源的激光头，一个三脚架，两个磁性支架 UM1（或 UM2），一个环境补偿套件 - （ECU）SM1，基础温度传感器 T1，T2，T3，1 个角度干涉仪 IK1，安装在 P100 毫米基座上的角度反射器 RK1，遥控闪光灯（可选）。

角度测量的辅助设备是：安装在支架上的两面镜子 ZK1，以反映激光束 - 表面平面度测量也需要；一个转台 SO1，由步进电机控制 - 用来测量定位角度。

Measurement of angle deviations

角度偏差测量

Preparations to measurements are similar to those described in the previous chapter. The measurements are executed in **Display** mode. Select **Angle** as type of measurements and select the measured axis (fig. 6.4). As a default, when the retro-reflector is bent towards the laser head direction, the measured value is positive. It is possible to change the sign in the option **Parameters – Change of sign**.

测量准备工作类似于前面章节中所描述的。测量在显示模式执行。选择角度测量类型和选择测量轴（图 6.4）。标准情况下，当反射器对激光头方向弯曲，测量值是正的。在选项**参数标志更改，**可以更改这个标志。

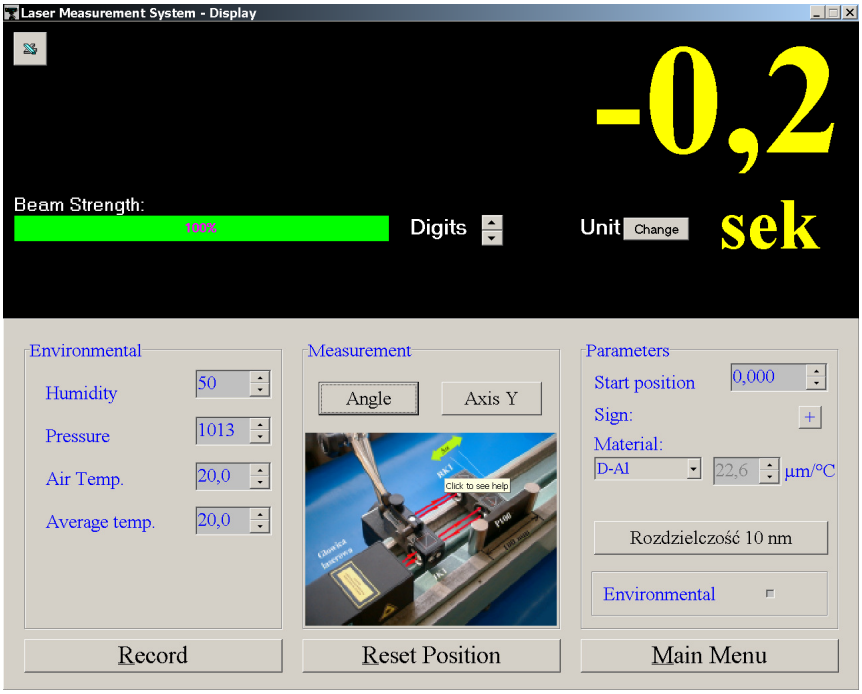


FIG.6.4. ANGLE DEVIATIONS MEASUREMENT SETUP.

（角度偏差测量设置）

After display reset the system is ready to measurements. If the retro-reflector is moved to a new point, the display shows the value of the angle deviation in relation to the first point. It is also possible to measure change of the angle deviation in the same point if the inclination of retro-reflector changes.

显示屏重置后，该系统就可以测量了。如果反射器被移动到一个新起点，显示屏显示相对于第一点的角度偏差值。也可以测量在同一点测量角度偏差变化，如果反射器的倾斜度发生变化。

Straightness measurements

直线度测量

The straightness measurements are performed moving the retro-reflector base along a straight line. In order to get the correct measurement the straight ruler, against which the retro-reflector base is pushed, should be fastened or fixed on the measured axis or surface. The measurement lateral surface of the retro-reflector base must **always** be tangent to the ruler (see fig. 6.5).

直线度测量是沿着一条直线移动反射器基座进行的。为了测量正确，与反射器基座对着推进的直尺，应该是固定在测量轴或表面。反射器基座各个测量侧面必须始终于直尺相切。（见图 6.5）

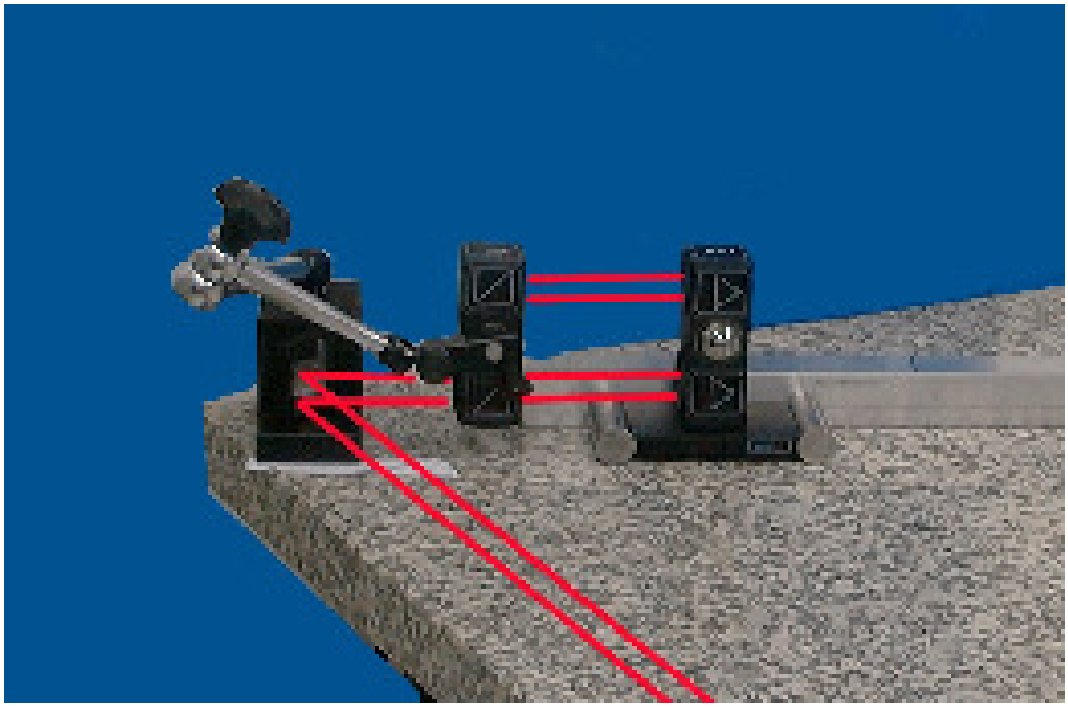


FIG.6.5. AN EXAMPLE OF OPTICAL COMPONENTS SETUP IN STRAIGHTNESS MEASUREMENT.

（直线度测量中光学元件设置的例子）

Required measuring set: a PC computer, a laser head with a laser interferometer power supply, a stand Tripod, two magnetic holders **UM1** (or **UM2**), a Environmental Compensation Unit - (ECU) **SM1**, sensors of basis temperature **T1**, **T2**, **T3**, an angular interferometer **IK1**, an angular retro-reflector **RK1** on a support base **P100** mm, a remote control Strobe.

所需的测量设置：一台电脑，一个带干涉仪电源的激光头，一个三脚架，两个磁性支架 UM1（或 UM2），一个环境补偿套件 - （ECU）SM1，基础温度传感器 T1，T2，T3，1 个角度干涉仪 IK1，安装在 P100 毫米基座上的角度反射器 RK1，遥控闪光灯。

The straightness measurement is performed keeping the angular retro-reflector against the ruler and moving at intervals of about 100 mm, and measuring its angle deviation. Before performing the measurements, you should mark reference positions at intervals of 100 mm on the leading ruler or on the examined surface. The use of a ruler with a scale is recommended. The straightness measurement is performed in the option **Straightness**, chosen from Menu Main (fig. 6.6).

直线度测量是保持角度反射器对着直尺，在 100 毫米左右的间隔移动，测量其角度偏差。在测量之前，你应该在直尺上或者所测表面标记 100 毫米间隔的参考位置。推荐使用一个带刻度的直尺。直线度测量要从主菜单（图 6.6）选择选项**直线度** 。

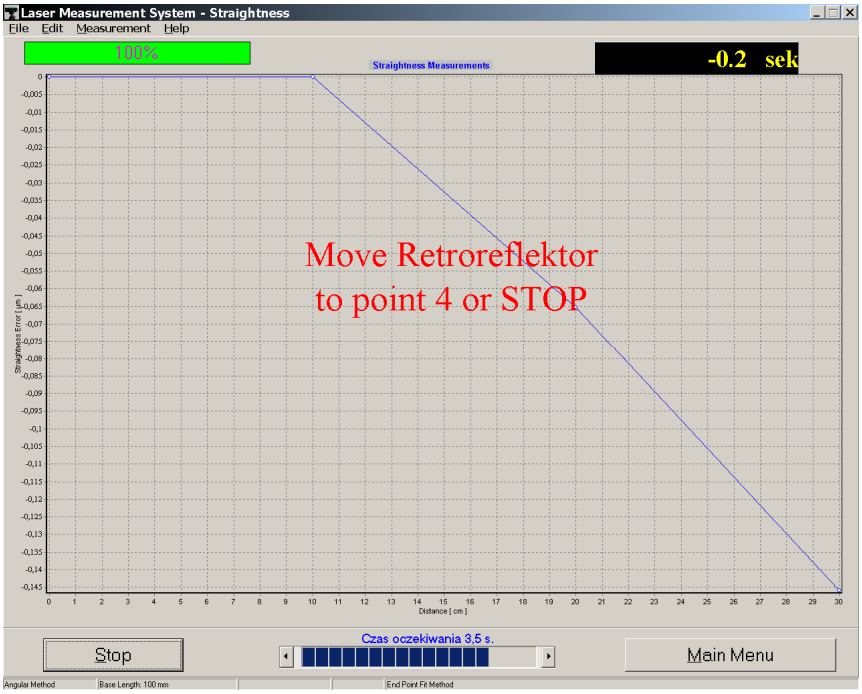


FIG.6.6. STRAIGHTNESS MEASUREMENT WINDOW.

（直线度测量窗口）

The measurement can be done in an automatic mode (standard arrangement) or in a manual mode with manual triggering of measuring points.

In the automatic mode capturing of the measuring points takes place after a selectable time delay. The time between capturing the measuring points is used to move the retro-reflector about a distance of 100 mm. The time interval should be used in dependence from practices of a person leading the measurements. It is suggested to set the time on 10 s and to decrease it if needed. An arrangement of the time interval may be done by pressing← , → keys on the computer screen. The retro-reflector base P100 should be placed at the beginning of the examined axis close to the interferometer. After the **Start** button is pressed one should wait on capturing the first measuring point. Then one should move the retro-reflector base of about 100 mm and to wait on the next point capture. Announcements shown on the computer screen make the measurement easy. After capturing the last measuring point press Stop.

测量可以在自动模式（标准安排）或在带手动触发测量点的手动模式完成。在自动模式下，测量点的获取发生在可选择的时间拖延后。获取测量点之间的时间是用于移动反射器大约 100 毫米的距离。时间间隔的使用取决于测量者的实践经验。建议设置时间为 10 s 再根据需要减少。间隔时间安排可通过按电脑屏幕上的 ， 键完成。该反射器基座 P100 应放置在所测轴的开始，接近干涉仪。按下**开始**按钮后，应该等待获取第一测量点。然后应该移动反射器基座约 100 毫米，并等待获取下一个点。显示在计算机屏幕上的报告使测量变得容易。获取最后一个测量点之后，按停止。

If from some reasons will not be possible to move the retro-reflector base before the capture moment, the measurement should be repeated from the beginning point and possibly the measuring interval should be enlarged.

如果因为某些原因，在获取测量点之前无法移动反射器基座，那么测量应该从开始点重复，也有可能测量间隔应该扩大。

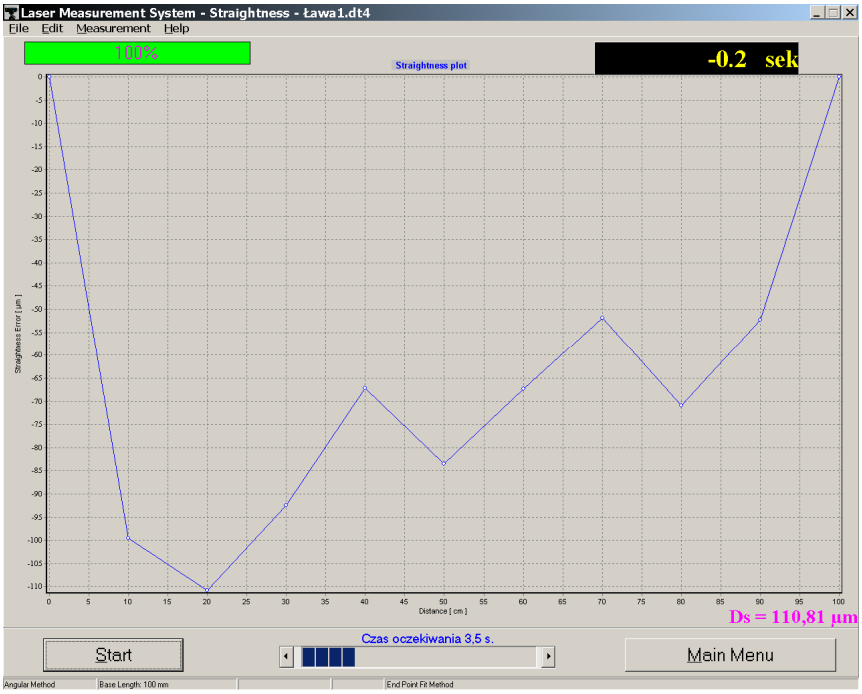


FIG.6.6. RESULT OF STRAIGHTNESS MEASUREMENT.

（直线度测量结果）

To perform the measurement manually, the option **Measurement automatic** in option **Measurement** should be switched off. The measurement is started by pressing **Start**. The Capture of the measuring points can be done from the computer keyboard or by pressing the remote Strobe button. Each time after the movement of the retro-reflector base of about 100 mm measuring point should be captured. After capturing the last point press **Stop**.

The results of the measurements may be saved to a file or printed according to the setup in **File** menu.

要执行手动测量，选项**自动测量**应该关掉。测量是按**开始**启动。测量点的获取可以从计算机键盘或按遥控闪光灯按钮完成。每次反射器基座移动约 100 毫米之后，测量点被获取。获取最后一个测量点之后，按停止。测量结果可被保存到文件夹或根据**文件**菜单设置打印

7

FLATNESS MEASUREMENTS

平面度测量

Preparation

准备过程

The flatness measurement is performed on the basis of straightness measurements of eight axes. After measurement values have been collected, a flatness 3D map is drawn. (fig.7.1.).

平面度测量是在 8 轴直线度测量的基础上执行的。测量值收集后，平面度 3D 地图绘制出来。（图 7.1）

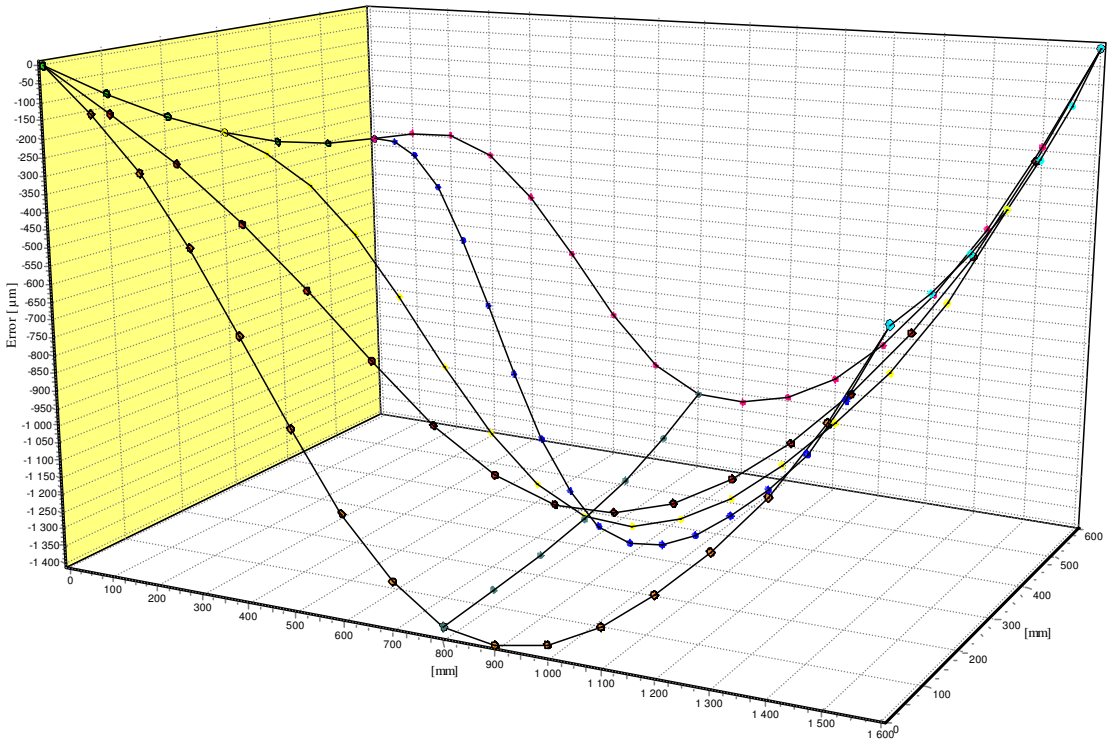


FIG.7.1. AN EXEMPLARY SURFACE FLATNESS MAP. （表面平面度地图示例）

Required measuring set consists of: a PC computer, a laser head with a power supply, a **Tripod** stand, two magnetic bases (**UM1** and/or **UM2**), a Environmental Compensation Unit - (ECU) **SM1**, basis Environmental Compensation Unit - (ECU) sensors (**T1**, **T2**, **T3**), an angle interferometer **IK1**, an angle retro-reflector **RK1** on a **P100** base and two beam directing mirrors **ZK1**. The element set for the flatness measurements is shown on fig. 7.2.

所需的测量设置：一台电脑，一个带干涉仪电源的激光头，一个三脚架，两个磁性支架（UM1 和/或 UM2），一个环境补偿套件 - （ECU）SM1，温度传感器 T1，T2，T3，1 个角度干涉仪 IK1，安装在 P100 基座上的角度反射器 RK1，2 个光束反射镜。平面度测量的元素套件见图 7.2。

FIG.7.2. FLATNESS MEASUREMENT KIT (**IK1, RK1** ON **P100** BASE AND **ZK1**)

平面度测量元素套装（ IK1 ， P100 基座上的 RK1 和 ZK1 ）

Adjustment of optics for the flatness measurements

平面度测量光学调整

The measurement of flatness consists of the measurements of deviations from straightness made along 8 axes. The measurement axes are set on a measured surface as shown on figure 7.3. On this figure are shown also: directions of measurements in the axes and margins that must be kept during measurements.

平面度测量包括沿 8 轴所作的直线度的偏差测量。测量轴在被测表面设置，见图 7.3。图 7.3 还显示：轴测量的方向，测量期间必须保持的空白。

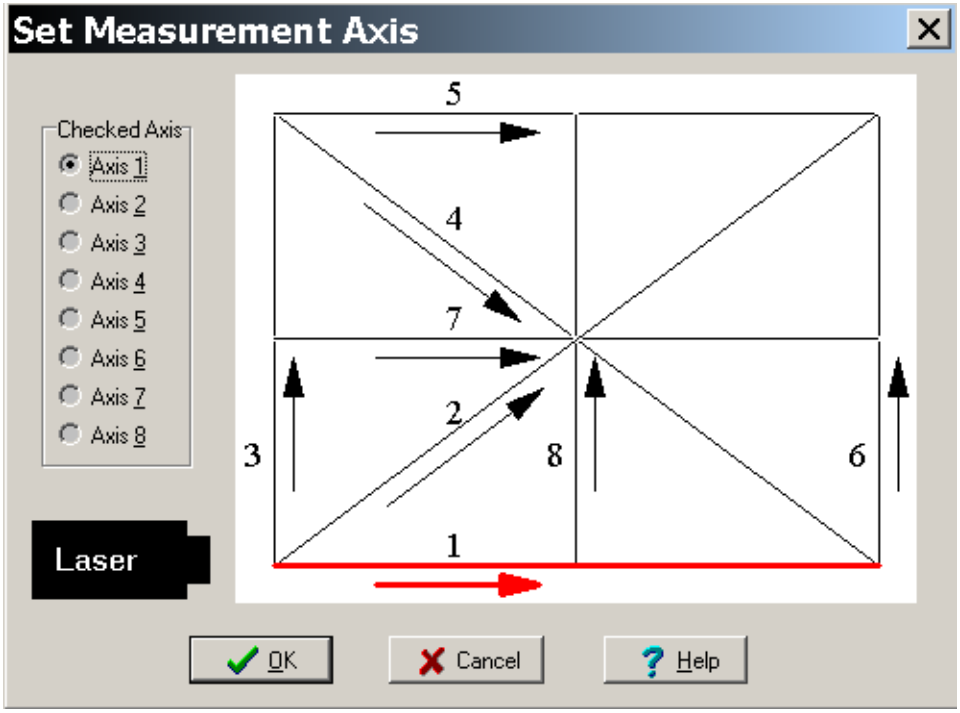


FIG.7.3. THE MEASUREMENT AXES.

（测量轴）

The measurements of deviations from straightness are made with angular optics as described in Chapter 6, *Straightness measurements*. Depending on the measurement axis, a different set of optical components is used and the adjustment of the optical path is done in slightly different way. All flatness measurements are done with one laser head position, shown on Figure 7.3.

The flatness measurements are performed in the option **Flatness** chosen from the **Main Menu**. After setting proper base length (standard is 100mm) and machine data (Edit->Machine Data and Edit->Base Length), the *Measurement* button should be pressed. Than a measured axis should be chosen (fig. 7.3) and then the optical path should be adjusted (see below). After the straightness of a chosen axis is measured a next axis should be chosen – Measurement->New Axis (fig. 7.4). When all the axes are measured, Flatness Plot button should be pressed. The received flatness plot (fig. 7.1) may be saved, printed or exported to a text file (File->Save, File->Print or File->Export).

直线度偏差测量是用角度光学元件完成的，如第 6 章*直线度测量*所述。根据测量轴，光学元件的不同套件被使用，光路调整以一个稍微不同的方式进行。所有的平面度测量在一个激光头位置完成，见图 7.3。

平面度测量要从**主菜单**选择选项**平面度**。在设置适当的基础长度（标准为 100 毫米）和机器数据（编辑->计算机数据和编辑->基础长度）后，应按下**测量**按钮。然后选择测量轴（图 7.3），调整光路（见下文）。所选轴的直线度被测量后，应选择下一个轴：**测量->新建轴**（图 7.4）。当所有的轴被测量后，应按**平面度曲线**按钮。接收的平面度曲线（图 7.1）能被保存，打印或导出到一个文本文件（文件 ->保存，文件->打印或文件->导出）。

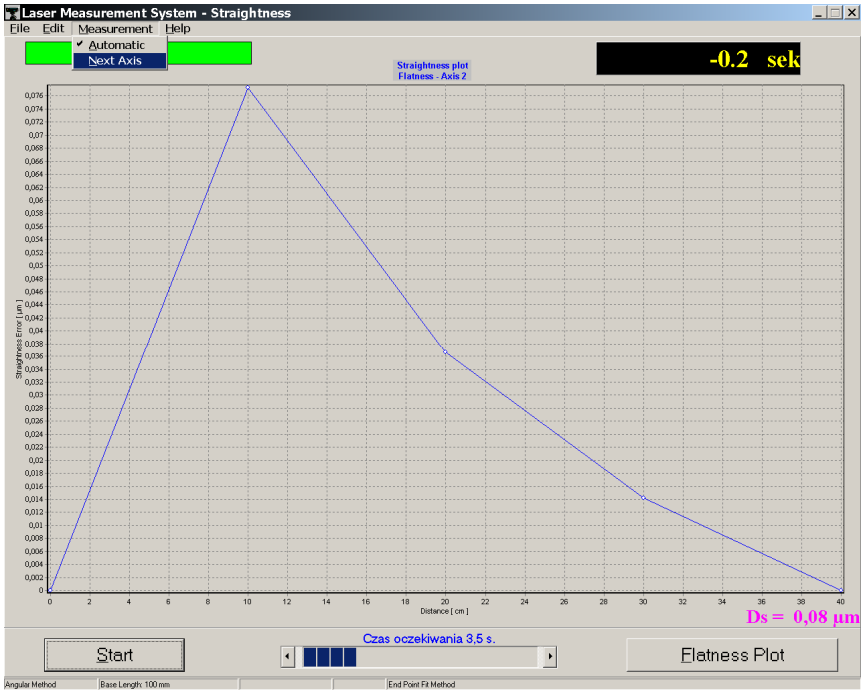


FIG.7.4. CHANGING AXIS IN FLATNESS MEASUREMENT.

（平面度测量轴的改变）

Optical path adjustment in the axis "1".

轴" 1 " 光路调整

The straightness measurement in the axis "1" is done with the optical components and in the way described in Chapter 6, *Straightness measurements*.

轴"1"直线度测量是用光学元件完成的，用第 6 章*直线度测量*所描述的方式。

Optical path adjustment in the axes: "3", "6", "8".

轴 " 3 " ， " 6 " ， " 8 " 光路调整

During flatness measurements in the axes "3", "6" and "8" an additional beam directing mirror **ZK1** is used. The way of using it is shown on Figure 7.5.

在轴 "3"，"6"和"8"平面度测量中，另外的一个光束反射镜 ZK1 要使用。使用方式如图 7.5 所示 。

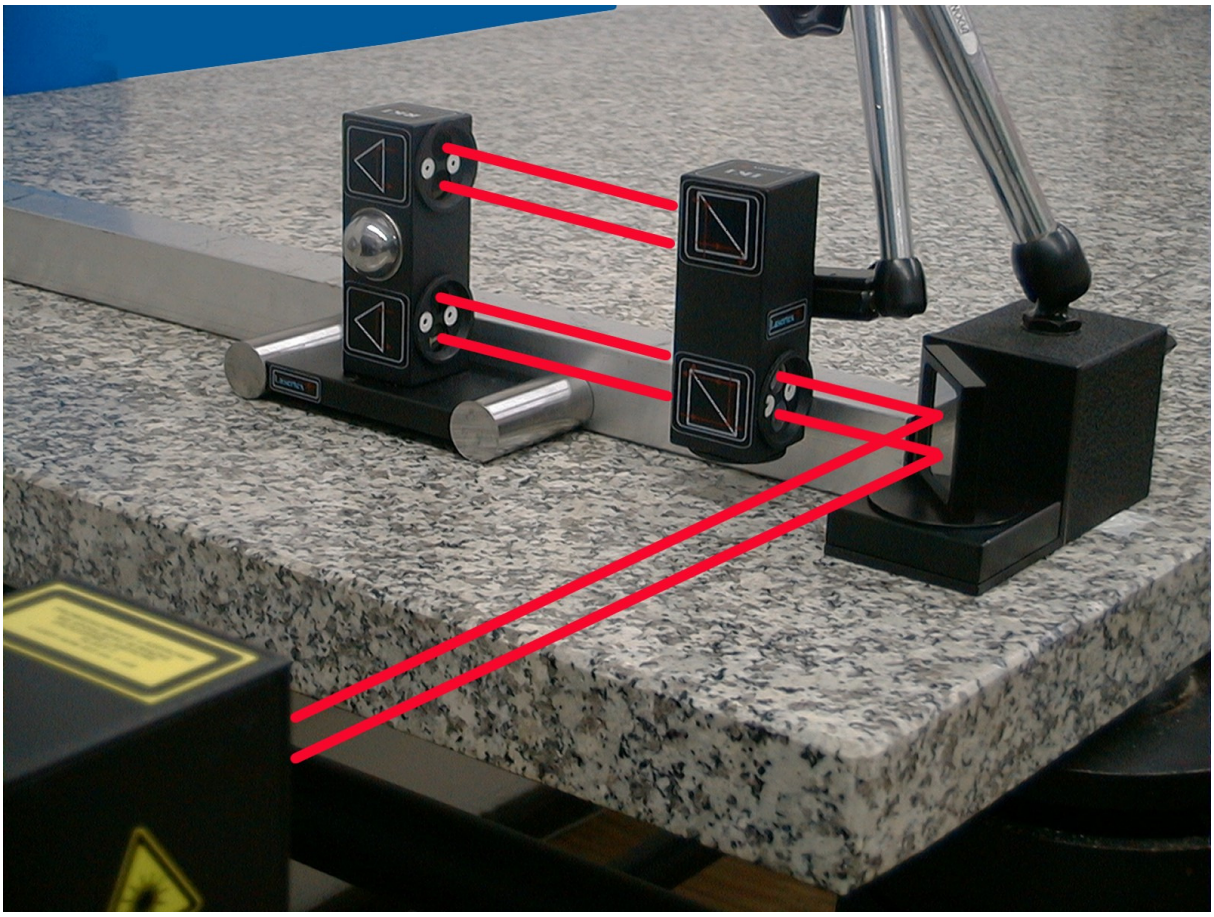


FIG.7.5. THE SET OF THE OPTICAL COMPONENTS USED IN STRAIGHTNESS MEASUREMENTS IN THE AXES: “3”, “6:” AND “8”

（轴“3”，“6”和“8”直线度测量中所用的光学元件套件）

1. The diaphragm on the laser head set to the *Adjustment* position,
2. The beam directing mirror **ZK1** set 45^{o} to the laser beam coming out from the head,
3. Place the angle interferometer **IK1** in the measured axis,
4. Set the diaphragm on the angle interferometer to the *Adjustment* position,
5. Change the position of the head so that the beam falls in the middle of upper interferometer’s diaphragm,
6. Set the diaphragm on the angle retro-reflector to the *Adjustment* position

7. Moving the retro-reflector along the axis, change the position of the head so that the beam passing through the interferometer falls also in the middle of the retro-reflector's diaphragm,
8. After changing the positions of the diaphragms on the interferometer and on the retro-reflector to *Working* positions, check if the return beam falls in the middle if measuring opening in the head. Do the check moving the retro-reflector along the axis. Corrections, if needed, can be made both changing the head or the interferometer position,
9. Set the diaphragm on the laser head to *Working* position and check if the level indicator on the display shows around 100%,
10. Now the straightness measurements, as described in Chapter 6, can be made.

1. 设置激光头光圈到调整位置，

2. 设置光束反射镜与从激光头射出的激光束夹角 45°，

3. 把 角度干涉仪 IK1 放在所测量轴上，

4. 设置角度干涉仪的光圈到调整位置，

5. 更改头部位置，使光束打在干涉仪光圈上部位置的中间，

6. 设置角度反射器光圈到调整位置，

7. 沿轴线移动反射器，改变头部位置，使光束通过干涉仪，也打在反射器光圈的中间，

8. 更改干涉仪和反射器上的光圈位置到**工作**位置后，检查返回光束是否打在中间，如果测量从头部开始的话。做检查时，可沿轴移动反射器。如果需要，可同时改变头部或干涉仪的位置，

9. 设置激光头上的光圈到工作位置，并检查屏幕上的位准指示器是否显示 100%左右，

10. 现在，直线度测量，如第 6 章所述，可以开始进行。

Optical path adjustment in the axes: "5" and "7"

轴“5”和“7”光路调整

During flatness measurements in the axes "5" and "7" two beam directing mirrors **ZK1** are used. The way of using them is shown on Figure 7.6.

在轴“5”和“7”平面度测量中，两个光束反射镜 ZK1 要用到。使用方法如图 7.6 所示 。

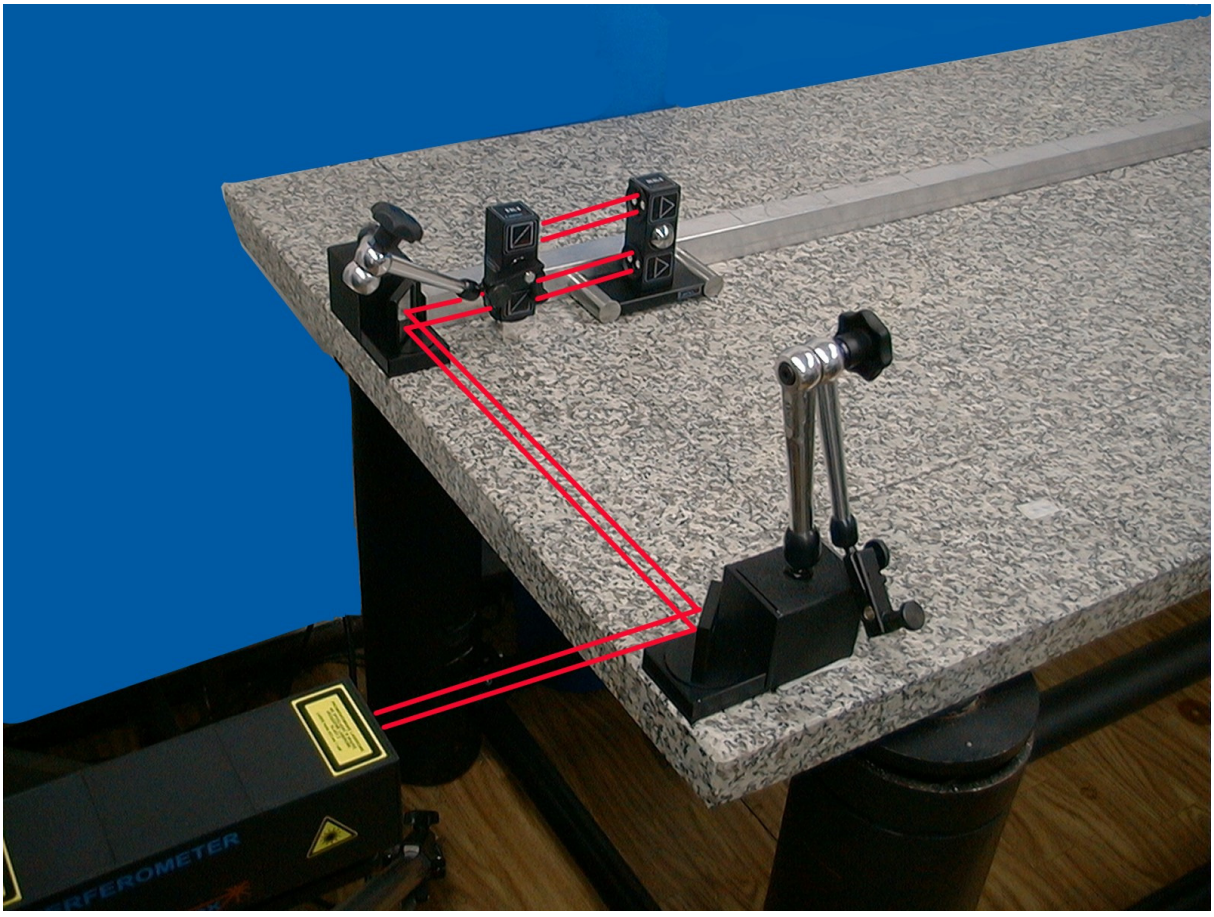


FIG.7.6. SET OF THE OPTICAL COMPONENTS USED IN STRAIGHTNESS MEASUREMENTS IN THE AXES: "5" AND "7"

（轴 “5” 和 “7”直线度测量中所用的光学元件套件）

1. The diaphragm on the laser head set to the *Adjustment* position,
2. The first beam-directing mirror **ZK1** set 45^{o} to the laser beam coming out from the head. The position of the laser head should be regulated in a way that the beam reflected from the first mirror runs parallel to the axis "3" and falls on the second beam-directing mirror. The second mirror is set 45^{o} to the first one,
3. Changing the position and the angle of the second mirror direct the reflected beam along the axes "5" or "7" in a way the beam is parallel to the axis,
4. Place the angle interferometer in magnetic holder of the second mirror and set it in the optical path,
5. Set the diaphragm on the angle interferometer to the *Adjustment* position,
6. Change the position of the head so that the beam falls in the middle of upper interferometer's diaphragm,
7. Set the diaphragm on the angle retro-reflector to the *Adjustment* position,
8. Moving the retro-reflector along the axis, change the position of the head so that the beam passing through the interferometer falls also in the middle of the retro-reflector's diaphragm,
9. After changing the positions of the diaphragms on the interferometer and on the retro-reflector to *Working* positions, check if the return beam falls in the middle if measuring opening in the head. Do the check moving the retro-reflector along the axis. Corrections, if needed, can be made both changing the head or the interferometer position,
10. Set the diaphragm on the laser head to *Working* position and check if the level indicator on the display shows around 100%,
11. Now the straightness measurements, as described in Chapter 6, can be made.

1. 设置激光头光圈到调整位置，

2. 设置 第一面光束反射镜 ZK1 与从激光头射出的激光束夹角 45 ° 。激光头的位置应规定在一个方式，使从第一个镜面反射的光束平行于轴“3”并打在第二面光束反射镜上。第二面镜子与第一面镜子夹角设为 45 ° ，

3. 改变第二面镜子的位置和角度，引导反射光束沿轴“5”或“7”，并使光束与轴平行，

4. 把 角度干涉仪放在第二面镜子的磁支架里，并把它设置在光路中，

5. 设置角度干涉仪的光圈到调整位置，

6. 更改头部位置，使光束打在干涉仪光圈上部位置的中间，

7. 设置角度反射器的光圈到调整位置，

8. 沿轴线移动反射器，改变头部位置，使光束通过干涉仪，也打在反射器光圈的中间，

9. 更改干涉仪和反射器上的光圈位置到工作位置后，检查返回光束是否打在中间，如果测量从头部开始的话。做检查时，可沿轴移动反射器。如果需要，可同时改变头部或干涉仪的位置，

10. 设置激光头上的光圈到工作位置，并检查屏幕上的位准指示器是否显示 100％左右，

11. 现在，直线度测量，如第 6 章所述，可以开始进行。

Optical path adjustment in the axes: "2" and "4"

轴“2”和“4”光路调整

Similar to previously described, during flatness measurements in the axes "2" and "4" two beam directing mirrors **ZK1** are used. The difference is that the angle of the second mirror usually differs from 45°. The way of using them is shown on Figure 7.7.

跟以前描述的类似，在轴“2”和“4”平面度测量中，两个光束反射镜 ZK1 要用到。不同的是，第 2 面镜子的角度通常不是 45°。该使用方法如图 7.7 所示。

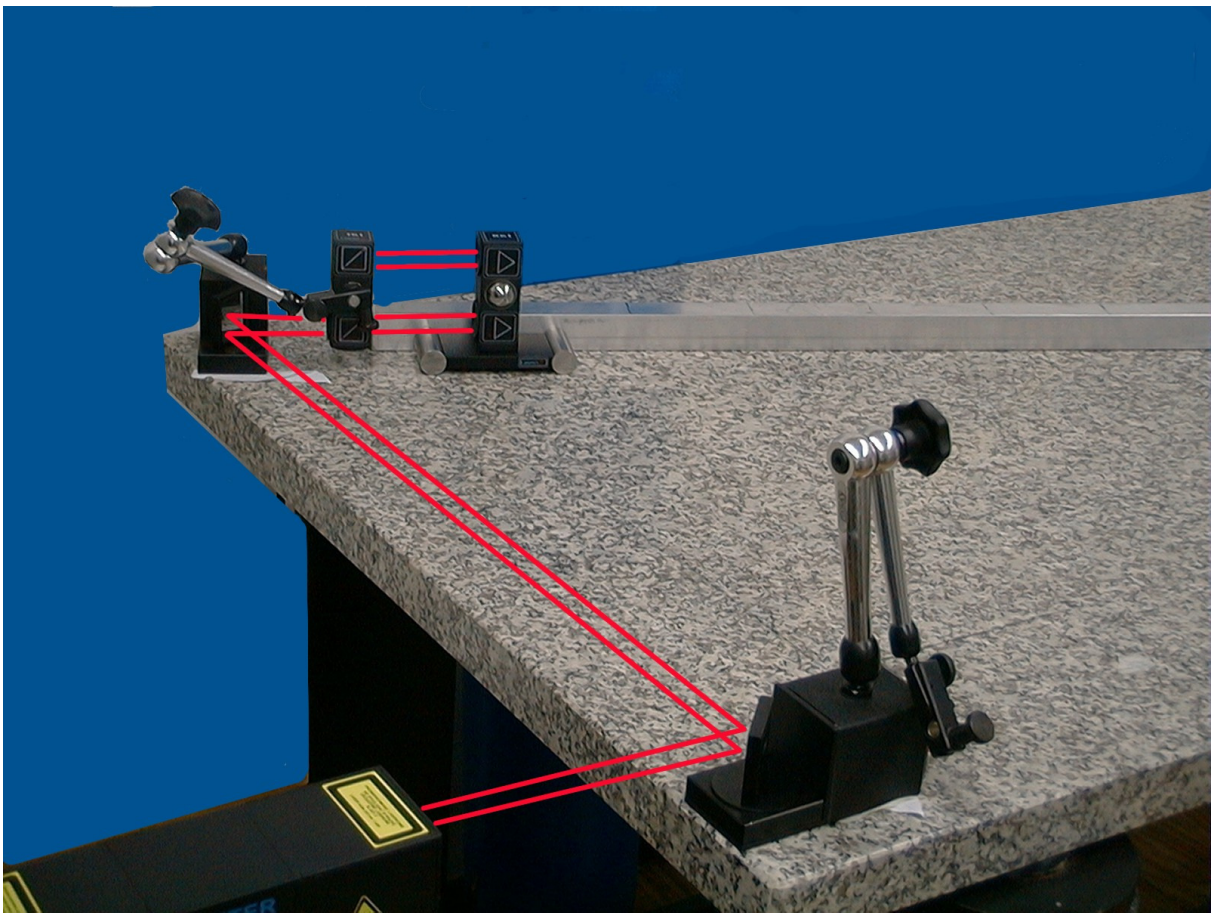


FIG.7.7. SET OF THE OPTICAL COMPONENTS USED IN STRAIGHTNESS MEASUREMENTS IN THE AXES: "2" AND "4"

(轴“2”和“4”直线度测量中所用的光学元件套件)

1. The diaphragm on the laser head set to the *Adjustment* position,
2. The first beam-directing mirror **ZK1** set 45^{o} to the laser beam coming out from the head. The position of the laser head should be regulated in a way that the beam reflected from the first mirror runs parallel to the axis "3" and falls on the second beam-directing mirror. The second mirror is set 45^{o} to the first one,
3. Changing the position and the angle of the second mirror directs the reflected beam along the axis "4" in a way the beam is parallel to the axis,
4. Place the angle interferometer in magnetic holder of the second mirror and set it in the optical path,
5. Set the diaphragm on the angle interferometer to the *Adjustment* position,
6. Change the position of the head so that the beam falls in the middle of upper interferometer's diaphragm,
7. Set the diaphragm on the angle retro-reflector to the *Adjustment* position,
8. Moving the retro-reflector along the axis, change the position of the head so that the beam passing through the interferometer falls also in the middle of the retro-reflector's diaphragm,
9. After changing the positions of the diaphragms on the interferometer and on the retro-reflector to *Working* positions, check if the return beam falls in the middle if measuring opening in the head. Do the check moving the retro-reflector along the axis. Corrections, if needed, can be made both changing the head or the interferometer position,
10. Set the diaphragm on the laser head to *Working* position and check if the level indicator on the display shows around 100%,
11. Now the straightness measurements, as described in Chapter 6, can be made.

1. 设置激光头光圈到调整位置，

2. 设置 第一面光束反射镜 ZK1 与从激光头射出的激光束夹角 45° 。激光头的位置应规定在一个方式，使从第一个镜面反射的光束平行于轴“3”并打在第二面光束反射镜上。第二面镜子与第一面镜子夹角设为 45°，

3. 改变第二面镜子的位置和角度，引导反射光束沿轴“4”，并使光束与轴平行，

4. 把 角度干涉仪放在第二面镜子的磁支架里，并把它设置在光路中，

5. 设置角度干涉仪的光圈到调整位置，

6. 更改头部位置，使光束打在干涉仪光圈上部位置的中间，

7. 设置角度反射器的光圈到调整位置，

8. 沿轴线移动反射器，改变头部位置，使光束通过干涉仪，也打在反射器光圈的中间，

9. 更改干涉仪和反射器上的光圈位置到工作位置后，检查返回光束是否打在中间，如果测量从头部开始的话。做检查时，可沿轴移动反射器。如果需要，可同时改变头部或干涉仪的位置，

10. 设置激光头上的光圈到工作位置，并检查屏幕上的位准指示器是否显示 100%左右，

11. 现在，直线度测量，如第 6 章所述，可以开始进行。

In the case of the measurements in the axis “2”, the path adjustment procedure is the same as described above The only difference is that the first mirror, as not needed, is not used.

在轴“2”测量中，路径调整步骤是跟上述一样的，唯一不同的是，第一面镜子，不需要，也不使用。

8

STRAIGHTNESS MEASUREMENTS – 3D

直线度测量-三维

Straightness/squareness measurement highlights any bending component or overall misalignment in the guideways of a machine. This could be a result of a wear in guideways, a collision or poor machine foundations. The straightness/squareness errors will have a direct effect on machine geometry and as the result on machining accuracy. The assessment of the machine geometry is one of the most important actions required when machine is setup.

直线度/垂直度测量强调机器导轨任何弯曲部分或整体偏差。这可能是导轨磨损，碰撞或较差机器基础造成的结果。直线度/垂直度误差将对机器几何产生直接影响，进而，影响机器精度。当机器运行后，机器的几何评估是最重要的行动之一。

The geometry measurements are one of the most time consuming measurements, the commonly used Wollaston prism optics is expensive and very difficult to adjust. Operation of the system with the Wollaston prism optics requires high skilled personnel. There are three methods available for straightness measurement: with angular optics, with Wollaston prism and with 3D method.

几何测量是最耗费时间的测量之一，常用的 Wollaston 棱镜光学系统价格昂贵，很难调适。操作沃拉斯顿棱镜光学系统需要很高端的技术人员。有三种方法可用于测量直线度：角度光学，Wollaston 棱镜和三维方法。

The method with the angular optics was presented in section ANGULAR MEASUREMENT. The optics with the Wollaston prism is supplied optionally. The method 3D of straightness measurement don't require any additional optics.
角度光学方法在角度测量部分已表述。Wollaston 棱镜光学方法可有选择的使用。三维直线度测量不需要任何额外的光学器件。

For squareness measurement one additional optical element is necessary – the optical square master. The straightness of the movement is measured by measuring of the position of the reference and position of the measuring beams returning to the laser head. 3D measurements offer unique possibility of measurements of straightness in two dimensions in one measurement. This significantly shortens the measurement time. Besides the 3D straightness measurement are done at the same time when the positioning measurements. After finishing the positioning cycle one can view the results of the straightness just by pressing "Straightness" on the positioning screen. It is also possible to measure the straightness in **Straightness** option in the main menu. For 3D measurements select 3D method of measurement from the "Measurement" menu or from the **Config** menu (on the main screen). The straightness measurement software procedure is the same like for straightness measurements described in "ANGULAR MEASUREMENT" section. In Fig. 8.1 the print screen made during the measuring process is presented. The automatic option of the measurement has been selected. In the left black rectangle see the position of the retro-reflector (in mm) is displayed, while in the upper and lower black rectangle the horizontal and vertical shift in micrometers are displayed.
对于垂直度测量来说，一个额外的光学元件是必要的 - 即光学直角尺。运动的直线度是通过测量参考位置和测量返回激光头的光束位置测量的。三维测量，在一次测量中，提供了两个维度上直线度测量的独特的可能性。这大大缩短了测量时间。三维直线度测量和定位测量可同时进行。完成定位周期后，按定位屏幕上的**直线度**按钮，可以查看直线度结果。也可以在**主菜单**的**直线度**选项测量直线度。对于 3D 测量，从"**测**

量”菜单或从**配置**菜单（在主屏幕）中选择三维测量方法。直线度测量软件程序是跟“角度测量”一节所述的直线度测量相同。图. 8. 1 显示测量过程中的打印屏幕。测量的自动选项已被选中。在左边的黑色矩形，可看到反射器的位置（毫米）显示，而在上部和下部的黑色矩形中，水平和垂直（微米）移位显示。

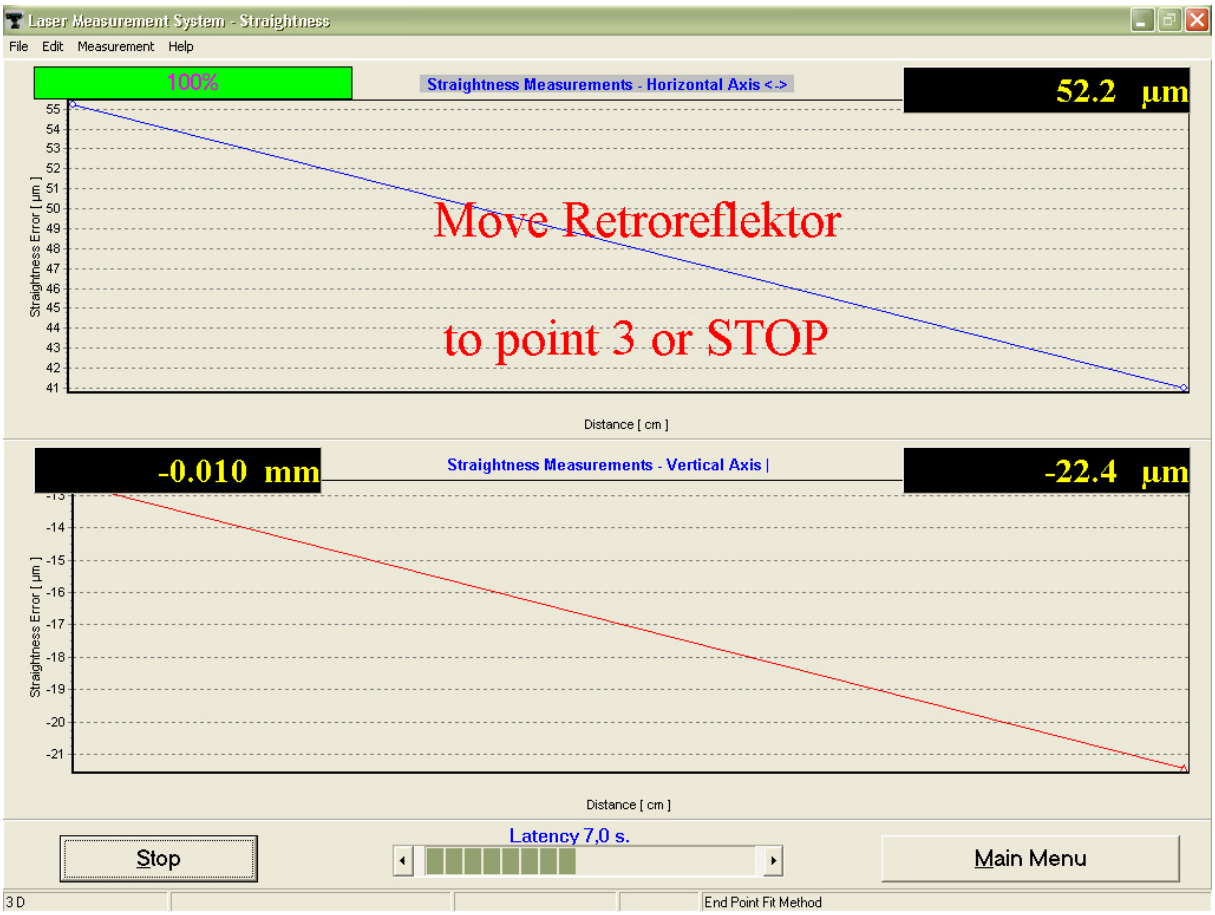


FIG. 8.1 PRINTSCREEN OF STRAIGHTNESS MEASUREMENT

（直线度测量打印屏幕）

The result of the measurements is presented in Fig.8.2. The upper trace shows the straightness for the horizontal plane and the lower one the straightness of the vertical plane. Parameter D_s represents the straightness error. End point fit method was chosen for plotting the result and for calculating of the straightness error.

测量结果如图.8.2 所示。上面的轨迹显示水平平面的直线度，下面的轨迹显示垂直平面的直线度。参数 D_s 代表直线度误差。选中按钮**终点选择方法**可以绘制结果和计算直线度误差。

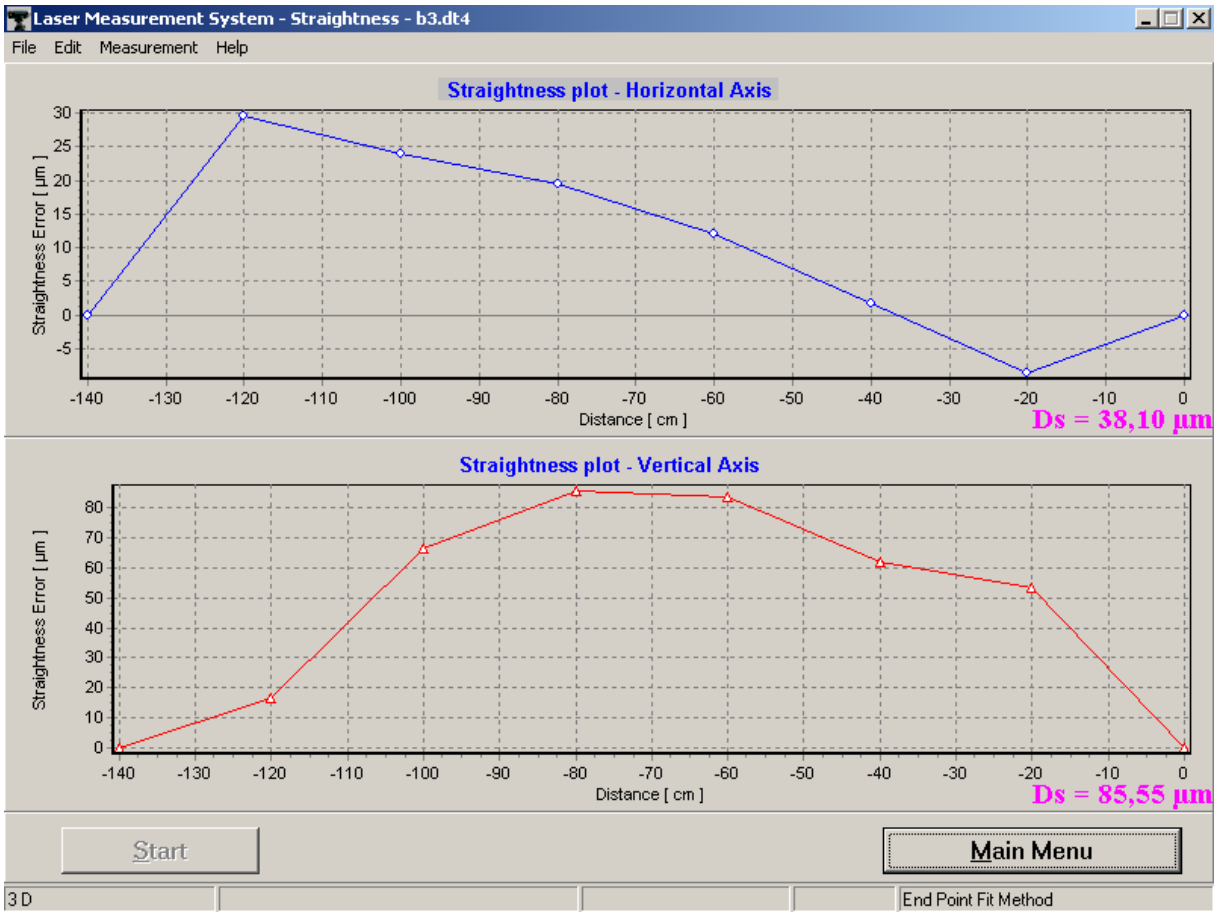


FIG. 8.2 RESULTS OF STRAIGHTNESS MEASUREMENTS.

（直线度测量结果）

The accuracy of the straightness measurements depends on the precision of the adjustment of the measured axis. It is recommended that the position of the crosses during adjustment (as seen on the **Display** screen) procedure to be set to the center of the screen (zero position). Vibrations of the base where the tripod is placed, and air density fluctuations are the causes which will affect the accuracy of the measurement. **When the required accuracy of straightness measurement for the tested machine is not satisfactory, it is necessary to perform measurements with the use of angular optics or with the Wollaston**

prism (which gives more accurate results, but needs more time for setup and optical path adjustment).

直线度测量精度取决于被测轴的调整精度。建议，调整过程中，交点位置（在显示屏幕上可看到）设置在屏幕的中心（零位）。放三脚架的地方的基座振动，空气密度波动都是影响测量精度的原因。当所测机器所需的直线度测量精度不理想，那就需要用角度光学或使用渥拉斯顿棱镜测量方法（这能给出更准确的结果，但需要花更多的时间来设置及调整光路） 。

9

VIBRATION MEASUREMENTS

振动测量

The laser measurement system LP30-3D is capable of detecting machine vibrations in the frequency range from 0 to 500 Hz. For these measurements an element set for linear measurements is used i.e.: a PC computer, a laser head with a power supply, a stand Tripod, magnetic holders (one **UM1** and one **UM2**), a linear interferometer **IL1**, and a linear retro-reflector **RL1**.The Environmental Compensation Unit - (ECU) and the temperature sensors do not have to be used. The optical path should be adjusted as shown in Chapter 4.

LP30 – 3D 激光测量系统能够检测频率范围从 0 到 500 赫兹的机器振动。这些测量需要线性测量的元素装置，即：一台 PC 电脑，带电源的激光头，一个三角架，磁性支架（1 UM1 和一个 UM2），线性干涉仪 IL1 和线性反射器 RL1. 环境补偿套件 – （ECU）和温度传感器没必要使用。光路调整见第 4 章所示。

To obtain correct results, it is necessary to select carefully the point where the retro-reflector will be connected to the body of the measured machine. If the point is chosen improperly then, a multiple frequencies *n*f* will be shown (where n=1, 2...) on the FFT chart, instead of a sought frequency *f*.

For that reason the retro-reflector **must not** be in theses measurements used on the magnetic holder **UM1**. It must be also remembered that the system measures vibration **only** in the axis of the optical path. Any vibrations in perpendicular axes do not influence the measurement (see fig8.1). An example of a properly attached retro-reflector is shown on fig. 8.2.

为了获得正确的结果，有必要仔细选择反射器连接到被测机器的点。如果点选择不当，那么，多频率 *n*f*，而不是所寻求的频率 f，将被显示在 FFT 图表上，（其中 n = 1,2 ,...），

由于这个原因，在测量中，反射器禁止用在磁性支架 UM1 上。还必须记住，系统只测量光路轴线的振动。垂直轴的任何震动都不会影响测量（见图 8.1）。正确的固定反射器的例子如图 8.2 所示。

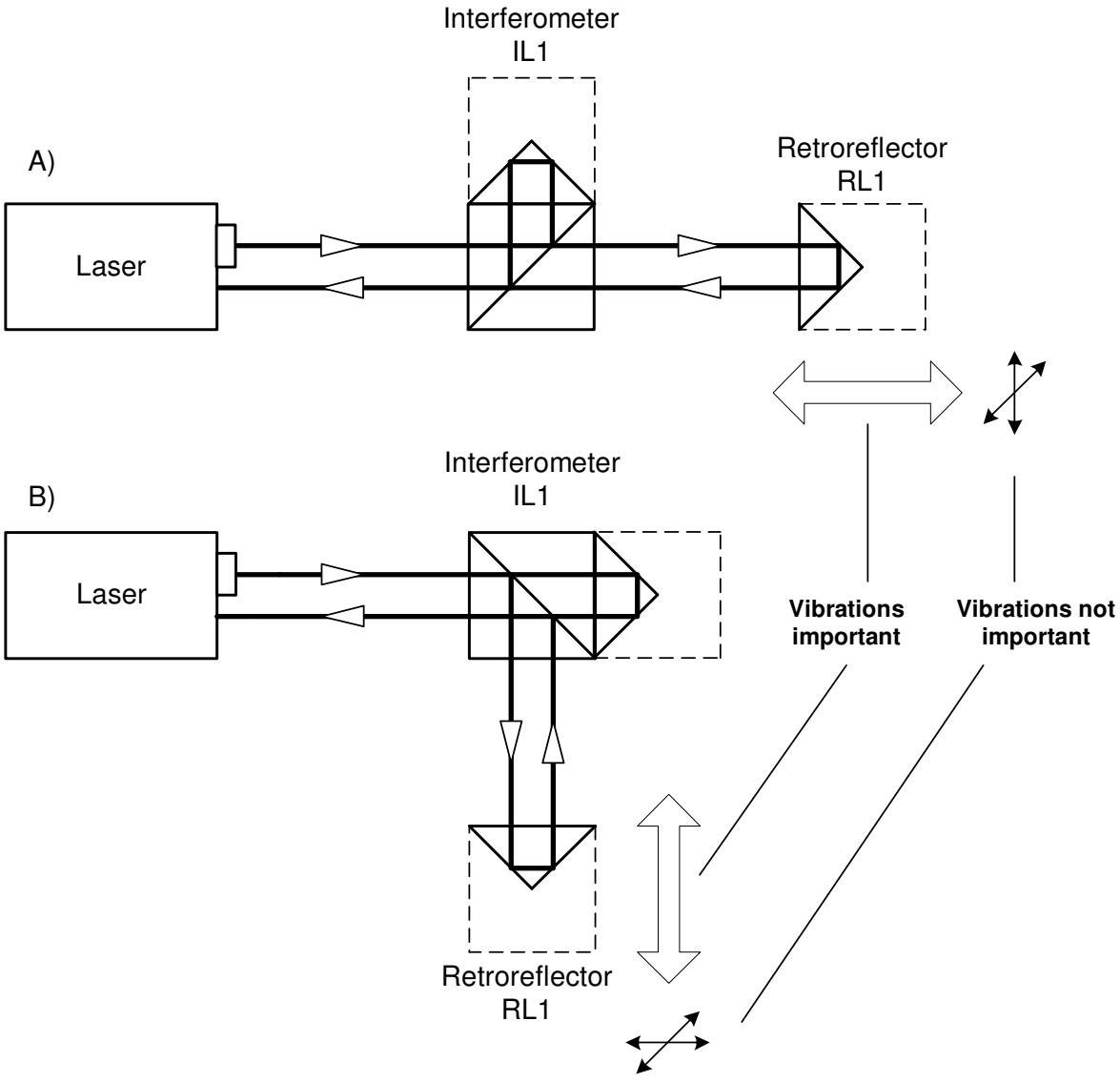


FIG.8.1. VIBRATION MEASUREMENT IN DIFFERENT AXES.

（不同轴线的振动测量）

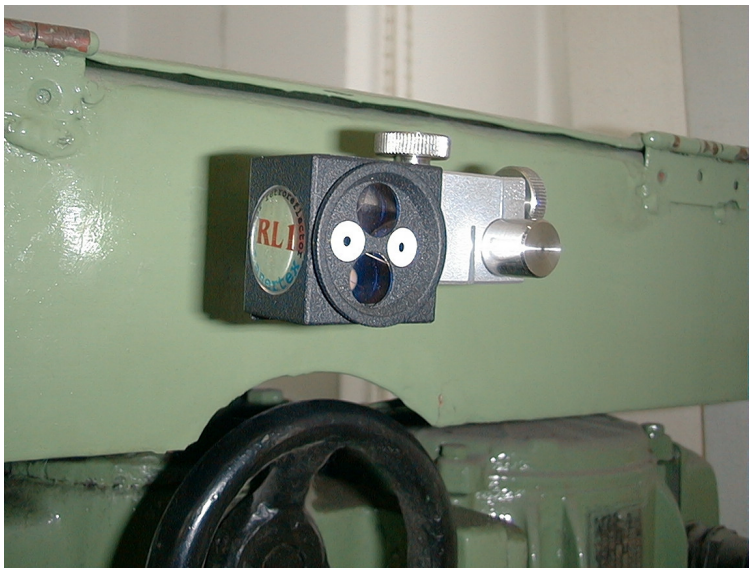


FIG.8.2. EXAMPLE OF PROPERLY ATTACHED RETRO-REFLECTOR.
（正确的固定反射器示例）

Measurements

测量

After adjusting the optical path and choosing **FFT** option from **Main Menu** a window, as shown on fig.8.3 appears. The most important parts of this window are: time diagram, frequency diagram and radio buttons (on the right side). Before measurements a machine data may be set (Edit->Machine Data). The measurement starts after pressing the Measurement button. Then appears the Measurement Window (see fig.8.3) that shows two progress bars – the upper (blue) one shows the progress in measurement; the lower (green) one shows progress in sending data to the computer. The measurement is in progress when the upper bar is in the range of 0-100% (it lasts approx. 12s)!

调整光路和从**主菜单**中选择 **FFT** 选项后，一个窗口出现，见图 8.3。该窗口最重要的部分是：时间图，频率图和单选按钮（右侧）。测量之前，机器数据可以设置（编辑->计算机数据）。按下测量按钮，测量开始。然后，测量窗口（见图 8.3）显示两个进度条 - 上面的（蓝色）显示测量进

度，下面的（绿色）显示将数据发送到计算机的进度。上面的进度条在范围 0-100%时，测量正在进行（它持续约 12 秒）！

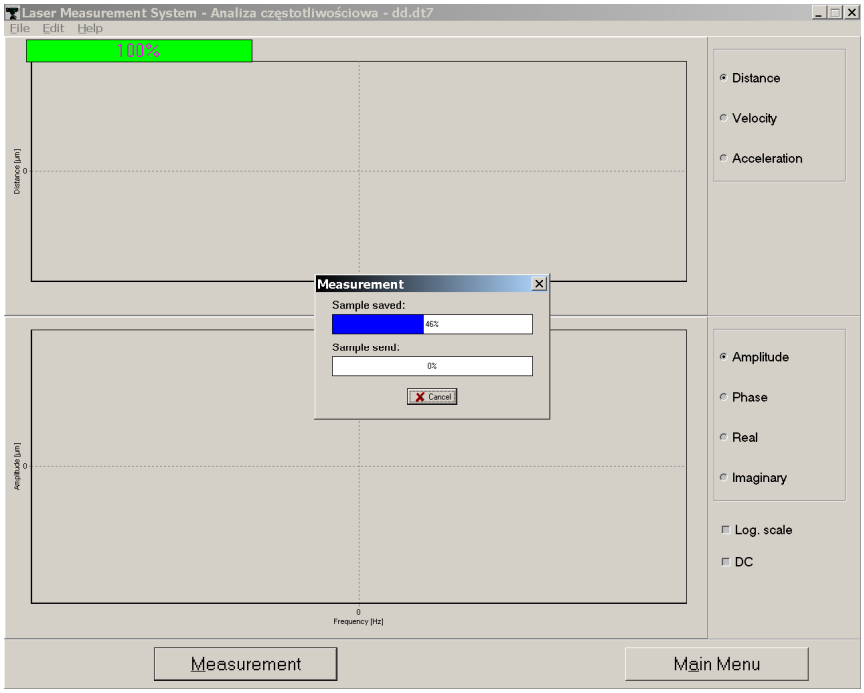


FIG.8.3. VIBRATION MEASUREMENT WINDOW.

（振动测量窗口）

When both the measurement and the transmission are done, the measurement results are presented on the time diagram and its FFT analysis on the frequency diagram (fig.8.4). The results can be saved, printed or exported (menu File). With the use of radio buttons the type of input data may be chosen, i.e. whether amplitude of Distance, Velocity or Acceleration is important. In the frequency diagram not only the amplitude of vibration frequencies may be displayed, but also their phase, and real and imaginary part of the vibration. The check buttons in the bottom right of the window allow to change the vertical scale of the frequency diagram to logarithmic and to eliminate a DC offset.

当测量和传输都完成后，测量结果显示在时间图及频率图（图 8.4）FFT 分析上。结果可以保存，打印或导出（**文件**菜单）。按单选按钮，输入数据的类型可以选择，即不论距离振幅，速度振幅或加速度振幅都很重要。在频率图上，不仅振动频率振幅会显示，它们的阶段以及振动实和虚的部

分也会显示。窗口右下角的查询按钮允许改变频率图的纵坐标到对数，以消除直流偏移。

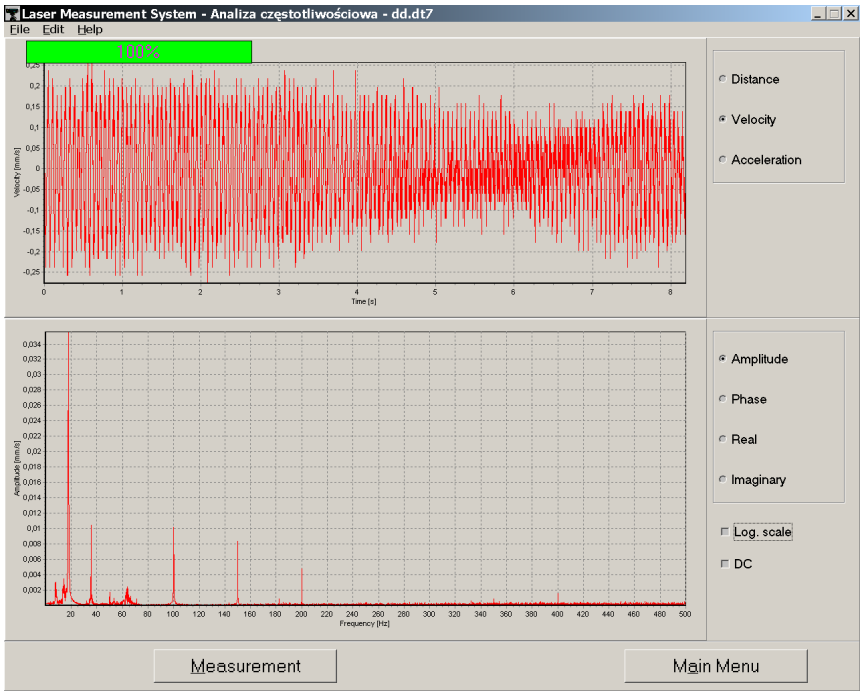


FIG.8.4. EXAMPLE OF VIBRATION MEASUREMENT RESULTS.

（振动测量结果示例）

What may be confusing in obtained results are different amplitudes of frequencies on the frequency diagram after changing from Distance to Velocity and to Acceleration, fig. 8.5. It happens so, according to the theory, from which results:

得到结果时，可能比较困惑的是频率图上频率的不同振幅，从距离变到速度，又从速度变到加速度（图 8.5）。这是根据理论发生的，结果含：

$E_{An} \sim f_n * E_{Vn}$

$E_{Dn} \sim f_n * E_{An}$

Where（其中）：

E_{Dn} – amplitude of n-th frequency when Distance is selected（选择距离时第 n 次频率的振幅）；

E_{Vn} – amplitude of n-th frequency when Velocity is selected（选择速度时第 n 次频率的振幅）;

E_{An} – amplitude of n-th frequency when Acceleration is selected（选择加速度时第 n 次频率的振幅）;

f_n – n-th frequency（第 n 次频率）.

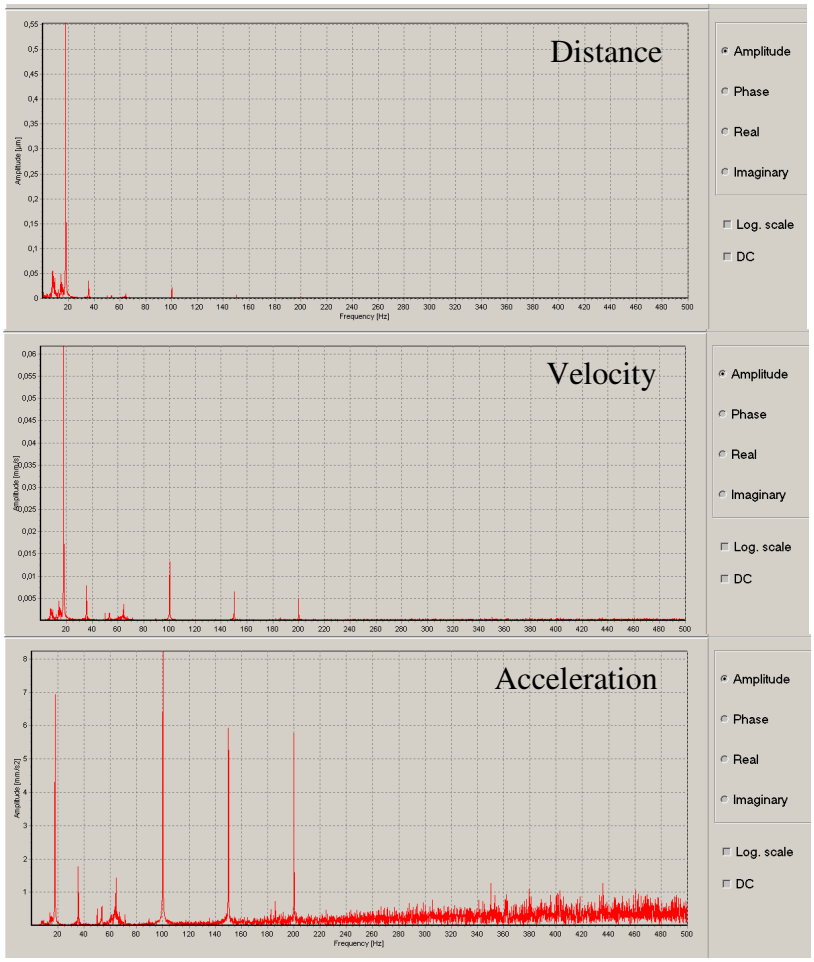


FIG.8.5. DIFFERENT FREQUENCIES' AMPLITUDES IN DEPENDANCE ON .

（距离， 速度，和加速度 不同频率的振幅）

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TECHNICAL DATA 技术数据

System specifications 系统规格

Measurement 测量	Range 范围	Resolution 分辨率	Accuracy 精度
Distance 距离	0 – 30 m	0,01 µm (0,001 µm)	0,41 µm/m
Velocity 速度	0 – 0,3 m/s (0,1 m/s)*	0.25 µm/s	0,1 %
Angular 角度	0 – 3600 arcsec 弧秒	0,04 arcsec 弧秒	± 0,2 %
Straightness measurement (with angular optics) 直线度测量（角度光学）	0 – 12 m	0,02 µm (for 100 mm base) （100 毫米为基础）	± 1 %
Flatness 平面度	0 – 12 m Vertical range ±2 mm 垂直范围±2 毫米	0,02 µm (for 100 mm base) （100 毫米为基础）	± 0,5 %
Straightness measurement (with Wollaston prism) 直线度测量（Wollaston 棱镜）	0 – 3 m	0.5 µm	± 1 %±(0.5±0.15L^2) µm
Straightness measurement 3D 直线度测量（三维 ）	0-10 m	0,1 µm	(3± 2 x L) µm L in meter
Squareness 垂直度	± 1000 arcsec 弧秒	0,4arcsec 弧秒	± 1 % ± (1,5 arcsec 弧秒)
Rotary measurements 旋转测量	± 5 °	0,04 arcsec 弧秒	± 0,2 %

L = axis length in meters （轴长度，单位米）

* For resolution 1 nm. *是指 分辨率 1nm

Laser head 激光头

Laser type 激光类型	Zeeman HeNe laser with frequency stabilization 塞曼氦氖稳频激光器
Heating time 预热时间	Approx. 20 min　大约 20 分钟
Wavelength (vacuum) 波长（真空）	632,991354 nm
Wavelength accuracy 波长精度	± 0,02 ppm
Short time stability 短时稳定性	± 0,002 ppm (1 hour)（1 小时）
Output power 输出功率	400 μW
Beam diameter 光束直径	8 mm
Distance between out- and ingoing beam 进出光束距离	12,7 mm
Laser head dimensions 激光头尺寸	60x60x245 mm
Net weight 净重	1500 g
Safety class 安全等级	Class 2 Laser product according to PN-91/T-06700 根据 PN-91/T-06700 , 属 2 级激光产品

System work conditions 系统工作条件

Temperature range 温度范围	10 – 35 °C
Humidity range 湿度范围	10 – 90 %

Power supply 电源

Voltage 电压	90-230 VAC, 50-60 Hz
Power 功率	35 W (during heating)(预热时) 10 W (work)（工作时）

PC interface 电脑界面

Type 类型	RS 232C, USB
Data rate 数据传输速度	57 600 bps (RS 232)

Environment compensation 环境补偿

Wavelength compensation 波长补偿

Manual 手动	Environments parameters entered from keyboard 键盘输入的环境参数
Automatic 自动	With the use of the Environmental Compensation Unit - (ECU) 使用环境补偿套件

Parameters of the Environmental Compensation Unit - (ECU) compensation

环境补偿套件参数

Air temperature 空气温度	Range 范围 0 – 40 °C, Accuracy 精度 0,1 °C
Pressure 压力	Range 范围 940 – 1060 hPa, Accuracy 精度 1 hPa
Humidity 湿度	Range 范围 10 – 90 %, Accuracy 精度 10 %
Time constants 时间常数	Temperature 温度 3 s, Pressure 压力 2s, Humidity 湿度 30 s
Dimension 尺寸	ϕ50x55 mm
Net weight 净重	100 g

Material temperature compensation 材料温度补偿

Manual 手动	Temperature of material entered from keyboard 键盘输入的温度材料
Automatic 自动	With the use of 1 to 3 temperature sensors 使用 1 至 3 个温度传感器
Temperature sensor 温度传感器	Pt-1000 in oil resistant casing 耐油罩壳中 Pt-1000
Time constant 时间常数	5 s
Net weight 净重	50 g

Our products are subject to continuous further development and improvement.
Subject to technical changes without prior notice
我们的产品在持续的进一步改善和发展，技术性调整恕不另行通知。