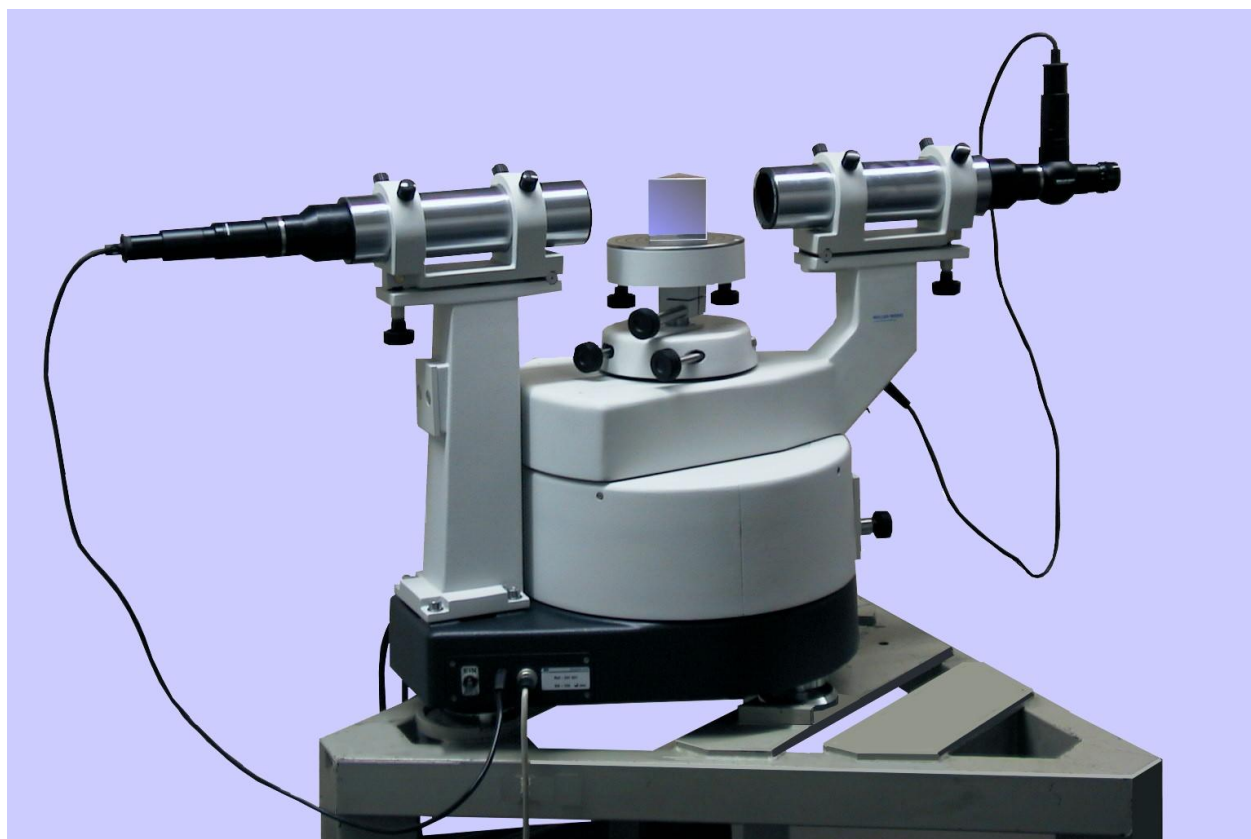


中文操作手册

Goniometer II / 测角仪 II 型

测量棱体角度及折射率



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介绍

MÖLLER 的 Goniometer II/测角仪 II 型是一台高精度的角度测量仪，可以适用于多种用途。通过对角度进行电子测量，并结合计算机评估，整个操作过程得以简化，操作时间得以缩短。

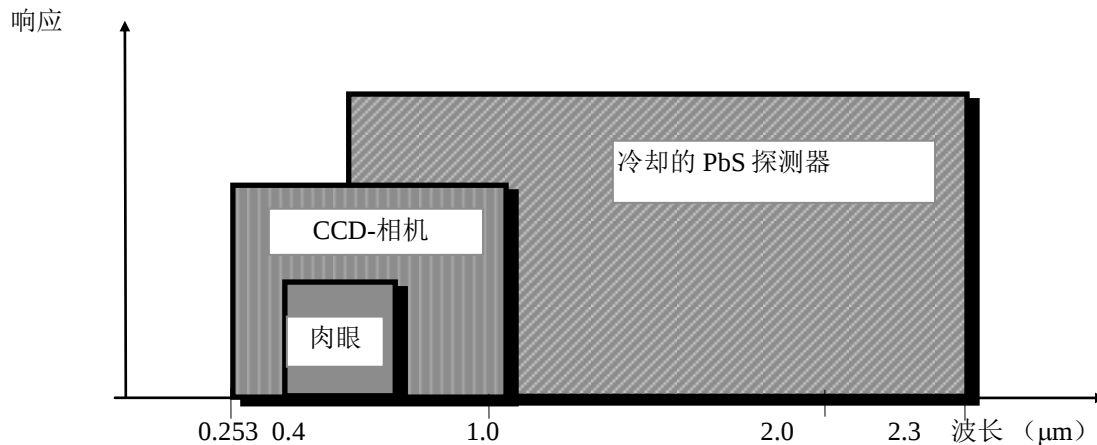
测角仪的读数是基于光电的原理。旋臂沿分划度盘的旋转将会两个电子传感测头上生成一个电子信号，以 180° 相互补偿。在进行处理之后，电子信号通过 Heidenhain 的控制卡 IK220 在计算机的显示器上显示出来。可测量的显示分辨率为 1 秒，在计算机上是 0.1 秒。

新型的带有 Heidenhain 控制卡的测角仪并不需要额外的角度显示器，测量数值也是直接从传感器传输至计算机。

通过使用光谱灯泡和滑动式滤光器，用户可以选择不同的光谱线，进行不同波长下的折射率的测量。

测角仪的模块式组合可以使它快速、便捷的转换为一台可见光下的分光光度计。如果要测量可见光下的折射率，您需要升级增加一个用于可见波长的光谱光源。

下图介绍了测角仪 II 型（可见光）及测角仪一分光光度计 II 型紫外—可见—红外下接收器的光谱响应：



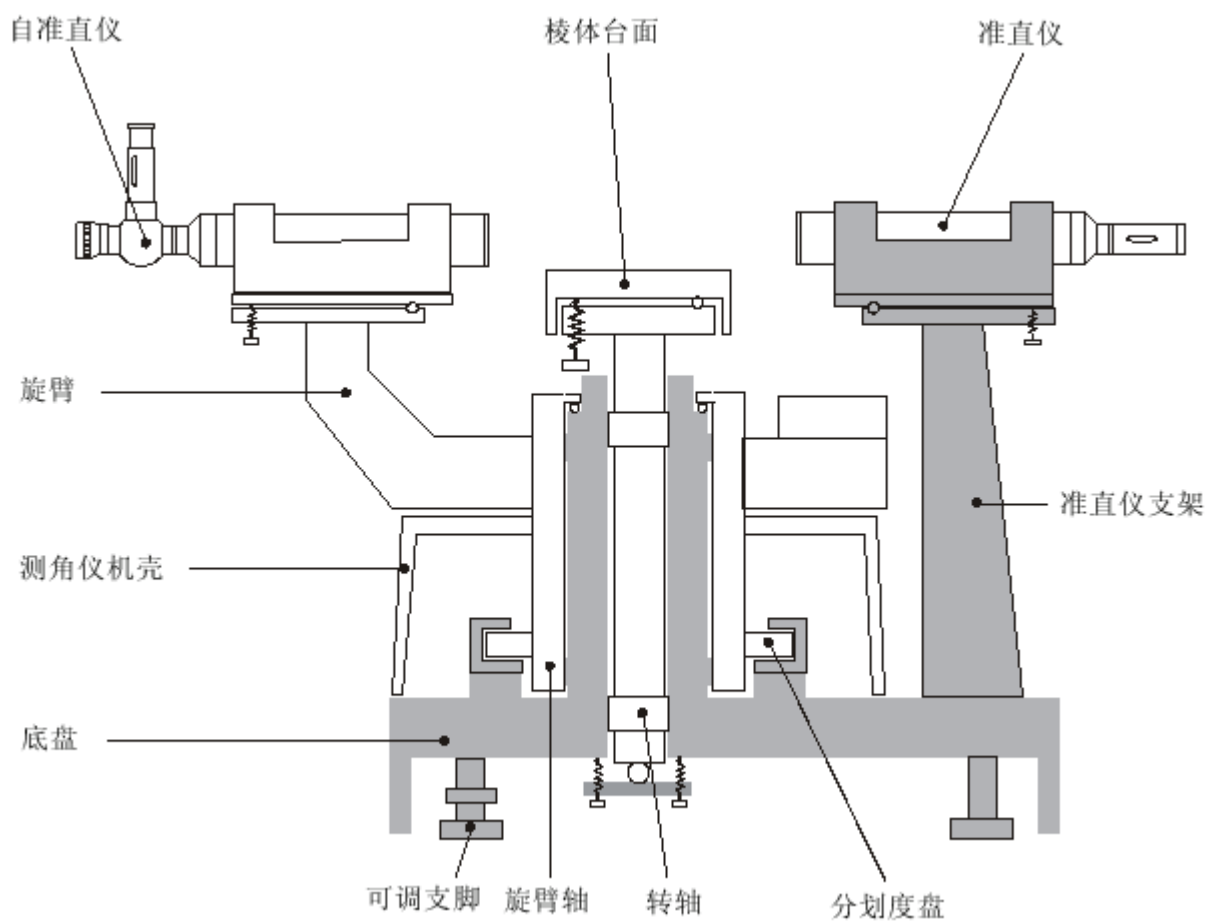
如上图所示，您可以根据需要测量的光谱范围，为特定的测量目的选取最佳的接收器。我们标准的测角仪 II 型只可以评估可见的范围（436 nm 至 644 nm）。

Möller 的测角仪一分光光度计 II 型可见光的结构如下图所示：

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A 开箱并安装测角仪 II 型

A.1. 安装地点

- o 将测角仪安装在一个稳定、避震的台面上。
- o 请使房间尽可能的没有温度波动。房间温度应在 20°C 左右。
- o 如果要测量小的棱体，那么黑暗的房间将提高肉眼观察时的对比度，令测量更为精确。
- o 如果你需要旋转 360° 进行测量，那么仪器所需要的工作直径至少 2.5 m。

A.2 设备清单

仪器编号:

仪器组件	订货号	o*	d*
- 测角仪 II 型基本主机, 包括:	241 021	x	—
- 棱体转台		x	—
- 自准直望远镜 (AKR 300/65/14.7)		x	—
- 连接电缆		x	—
- 准直仪支架		x	—
- 准直仪 (K300/65)		x	—
- 变压器 (220 V/2-6V)		x	—
- 变压器至测角仪的连接电缆		x	—
- Heidenhain 控制板 IK220		x	—
- 标准奔腾计算机, 一套, 预装 WINDOWS XP		x	—
- 连接传感器的 2 条电缆		x	—
- 装入工装的玻璃平晶		x	—
- 光谱设备 VIS 可见光	241 025	x	—
- 光谱灯泡: HgCd/10	123 114 13	x	—
- 三角架, 高度可调, 马达驱动	241 190	x	—
- GonioWin 软件	241 200 01	x	—
- 测角仪软件操作手册	241 200 02	x	—
- 操作手册	241 021 01	x	—

*) o: 订购的, d: 供货的

A.3. 开箱

- * 打开纸箱。
- * 打开内部的纸箱。
- * 现在，您将看到一个木制托盘。通过木质托盘的提手抬出仪器。这项工作必须由至少两个人完成！

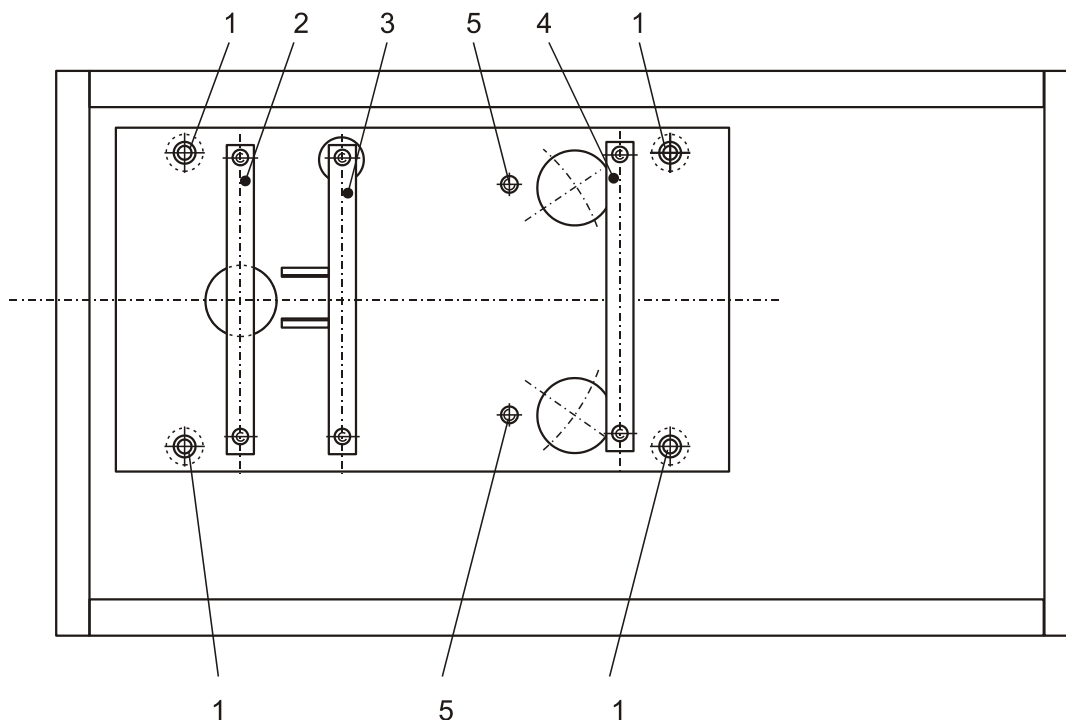
小心!

小心，仪器非常沉！

- * 从木杆中旋下上面的木制托盘（A.1.1.）。
- * 旋下固定器（A.1.2, A.1.3 及 A.1.4），并取下保护层。
- * 旋下木制托盘（货盘）下面的两个螺丝（A.1.7.）。

只可通过底盘的机体搬运仪器，禁止通过旋臂或突出部件。将仪器轻轻的放下，不要旋转它。

图 A1) 仪器运输时的固定方式：



A.4. 安装仪器

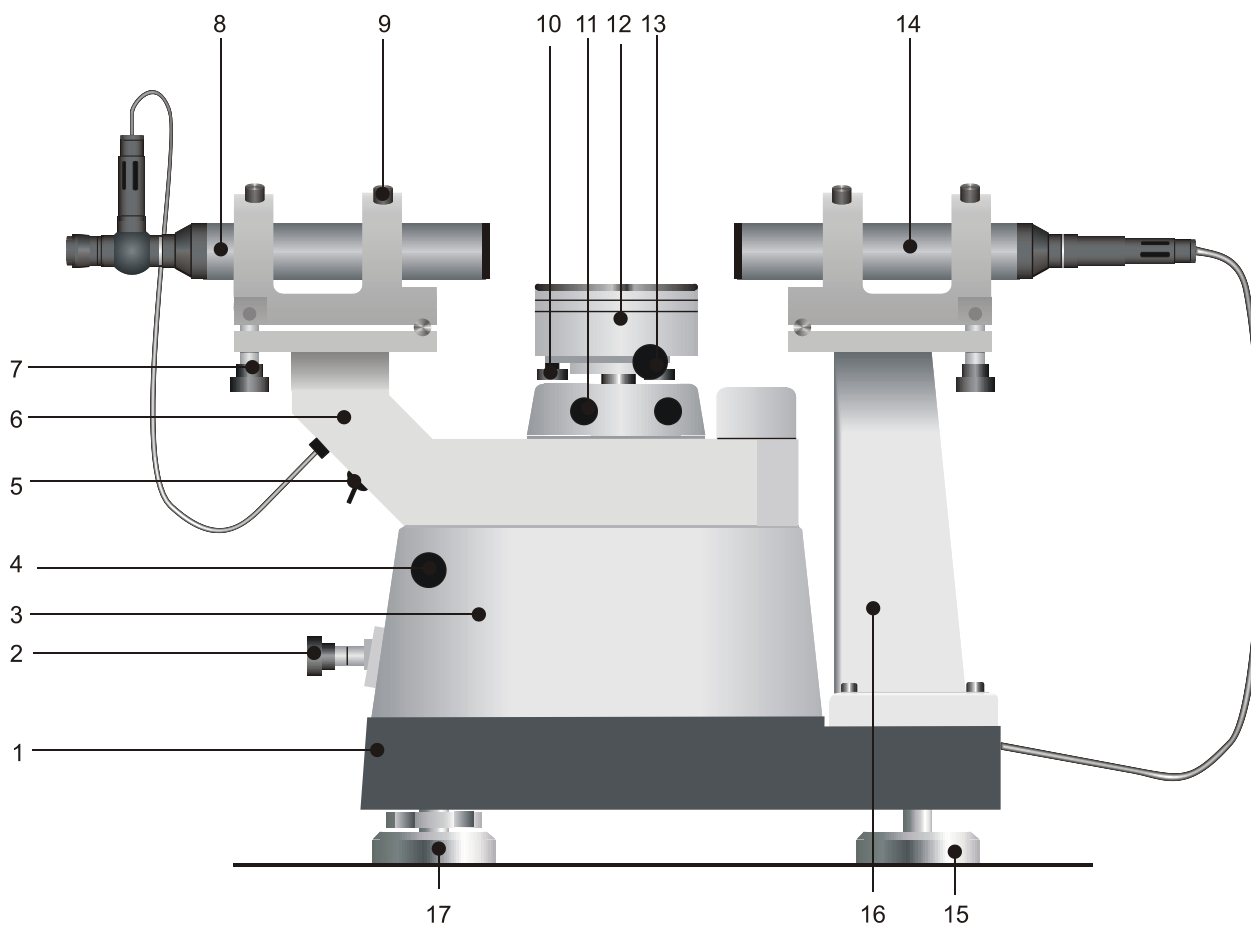


图 A1: 测角仪 II 型

- 1 - 底盘
- 2 - 旋臂的紧固螺丝
- 3 - 测角仪机壳
- 4 - 精调螺丝，用于以秒为单位旋转旋臂
- 5 - 自准直望远镜光源的接口及开关
- 6 - 旋臂
- 7 - 精调螺丝，用于自准直仪的水平调整
- 8 - 自准直仪
- 9 - 夹具的紧固螺丝
- 10 - 精调螺丝，用于转台的倾斜调整
- 11 - 转台的紧固螺丝
- 12 - 转台
- 13 - 精调螺丝，用于转台旋转
- 14 - 准直仪
- 15 - 固定支脚
- 16 - 准直仪支架
- 17 - 可调支脚

- * 请至少以两人将仪器抬至预定的安装地点。

只可通过底盘的机体搬运仪器，禁止通过旋臂或突出部件。将仪器轻轻地放下，不要旋转它。

- * 借助水平仪通过底脚螺丝（A2.17）放平仪器。

o 棱体转台

将棱体转台（A2.11）放于测角仪转轴上并通过紧固螺丝固定（A2.11）。

o 自准直望远镜（（A2.8）

- * 将自准直望远镜（AKR300/65/14.7）滑入旋臂的夹具中，并轻轻地用螺丝紧固它。
- * 将光源装入自准直仪的光管中，并将其插头插入旋臂的连接插座中。

o 准直仪

- * 利用 4 个套筒螺丝将准直仪支架（A2.16）装在测角仪 II 型的底盘（A2.1）。
- * 将准直仪滑入夹具中，并轻轻地用螺丝紧固它。将光源装入准直仪的光管中，并将其插头插入底盘的连接插座中。

- o 用连接电缆将测角仪与变压器连接（DIN, 4 极），将变压器接入 230V/50Hz 主电源。

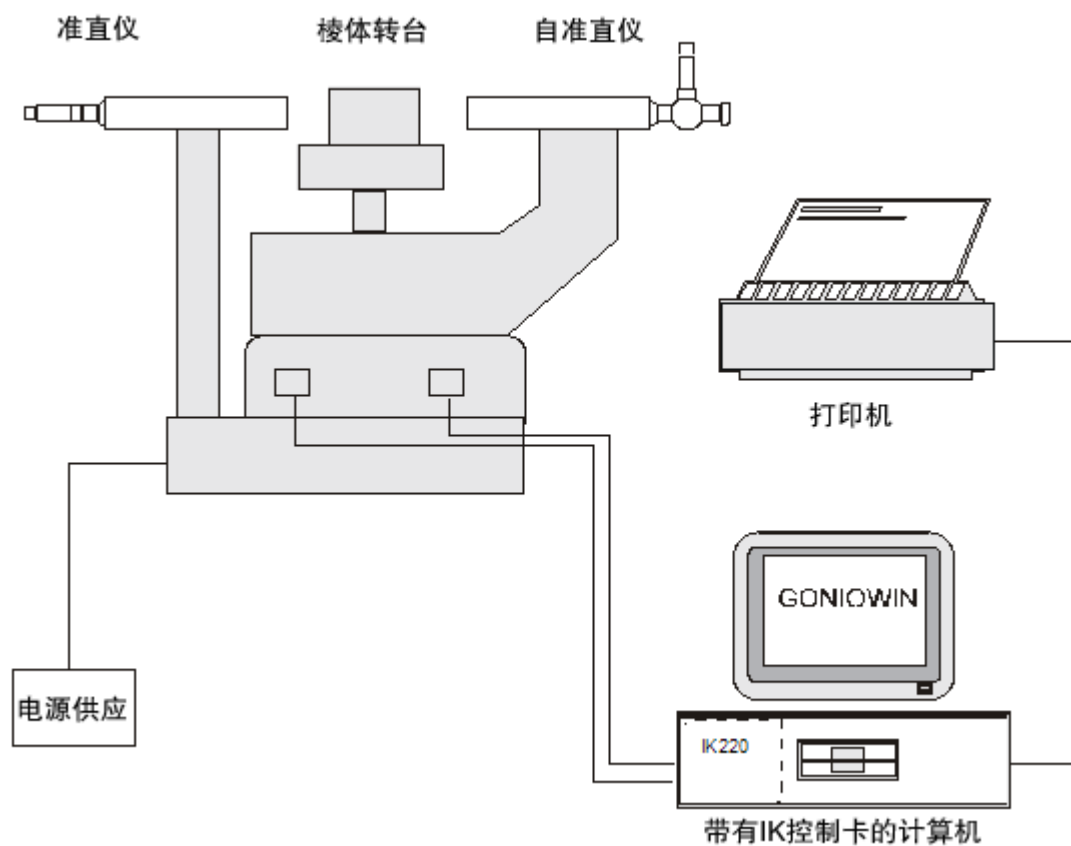
o 角度显示系统

连接角度部件（通过连接线缆将 Heidenhain 控制卡 IK121 与测角仪相连）。如果不使用，这些插座必须用防尘盖遮蔽，以防止灰尘进入内部。

o 计算机

一般来说计算机是预装好的。控制卡安装在一个空闲的 ISA 插槽中。连接线缆（5m 长）将测角仪的输出端口（共有 2 个，分别连接至 Heidenhain 度盘的两个电子传感器）连接至控制板的输入端口。我们建议在连接、拨下线缆时关闭仪器的电源。

接线图:



B 测角仪介绍

B.1 底盘

底盘 (A2.1) 具有一个固定支脚和两个可调支脚 (A2.17 及 A2.15)。在底盘上有一个水平仪, 并有一个插座以连接准直仪及自准直望远镜光源的供电线缆。第二个插座是用于连接角度显示单元。

B.2 分划度盘

该分划度盘具有 36000 线及两个相对而设的传感测头。旋臂的每一次旋转将生成一个电子信号, 并被转换为角度。该角度的数值在角度显示单元上以十进制或秒为单位得以显示 (配有 Heidenhain 控制板的计算机)。该显示可以在 0.0001° 及 $1''/0.1$ “间进行选择。单位测量的精度优于 3”, 连续测量的精度优于 0.6”。

不配有准直支架的测角仪的操作范围为 360° 。旋臂可以用手或精调螺丝 (A2.4) 操作。它可以通过螺丝 (A2.2) 固紧。

B.3 棱体转台

该棱体转台的直径为 135 mm。

它具有一个固定支脚和两个可调支脚 (A2.10), 它们与中心点呈 90° 分布。

松开固紧螺丝 (A2.11) 后可以调整它的高度。

可以在松开紧固螺丝 (A2.11) 后用手或在旋紧紧固螺丝 (A2.11) 后用精调螺丝 (A2.13) 旋转该棱体转台。

B.4 准直仪 K300/65

准直仪（图 B1）是一台光学准直仪，其焦距为 300 mm，管直径 65 毫米，自由孔径 50 mm。其光学元件是由玻璃（消色差物镜）构成，通光范围从 400 nm 至 1500 nm。

在其后焦平面上，该准直仪设有一个分划（单十字线）。

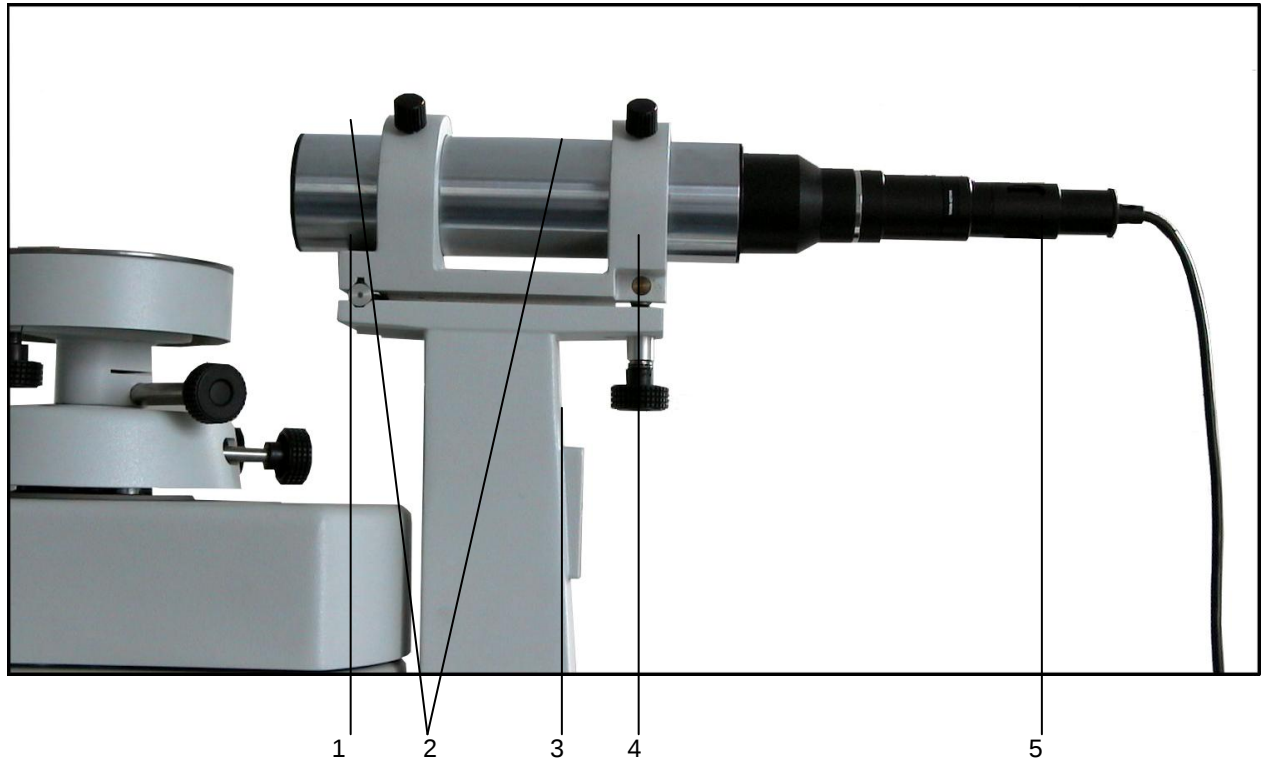


图 B1：装在夹具中的准直仪（1—夹具，2—紧固螺丝，3—水平倾斜调整螺丝，4—准直仪，5—准直仪光源）

B.5 自准直望远镜 AKR 300/65/14.7

该自准仪是一个光学自准直仪，其焦距为 300 mm，管直径 65 mm，自由孔径 50 mm。它的光学元件材质为玻璃（消色差透镜），通光波长约 400 nm 至 1500 nm。在其后焦平面，该自准直仪设有一个单十字线及一个双十字线。

在自准直仪的焦平面上有一个单十字刻线（近准直仪端）及一个双十字刻线（近望远镜端）。

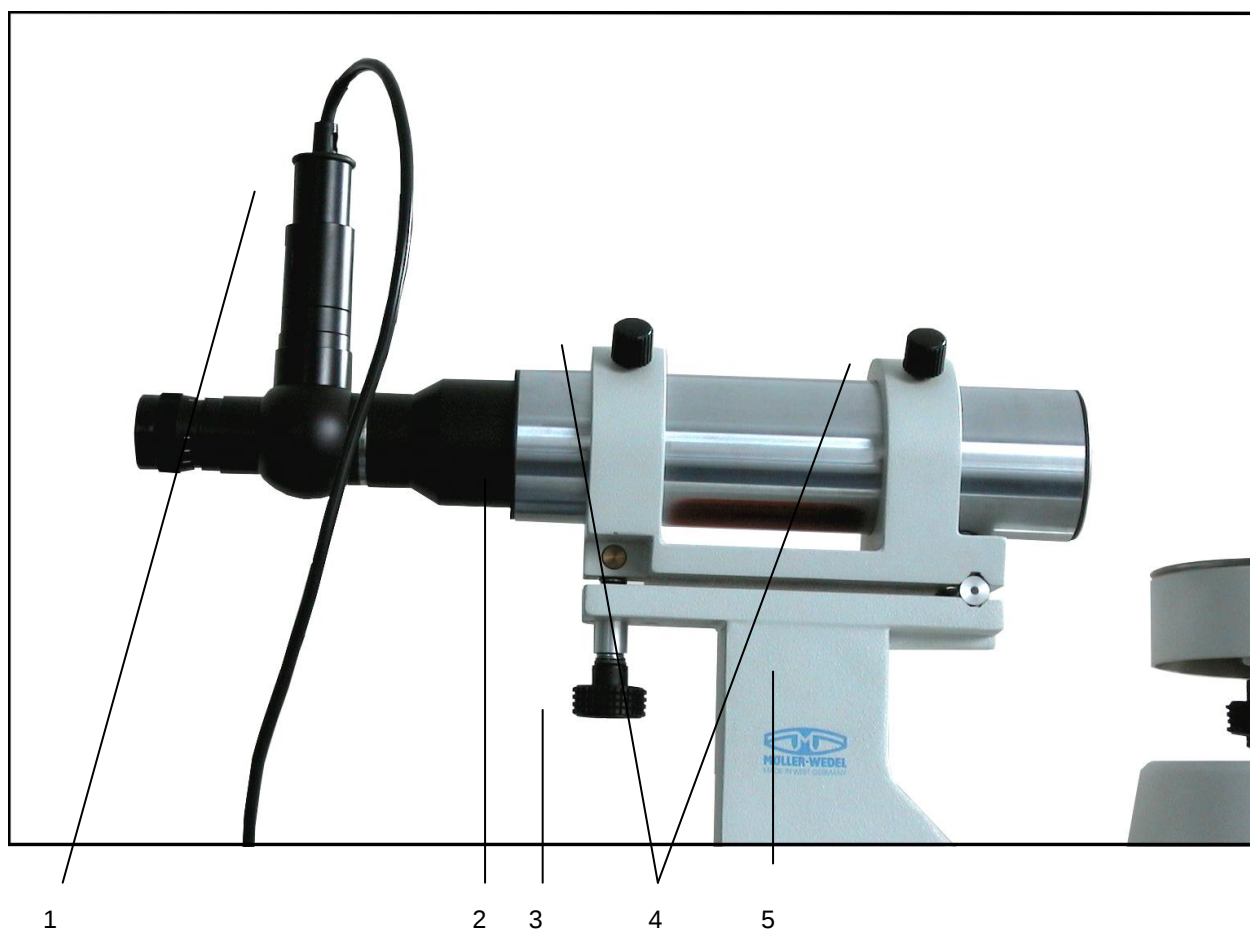


图 B2: 装在夹具中的自准直仪（1—光源，2—自准直仪，3—水平调整用螺丝，4—紧固螺丝，5—旋臂）

C 测角仪的基本调整

在仪器完全安装好后，您需要进行基本的调整。这包括测角仪的水平调整、自准直望远镜（如需要，包括准直仪）就测角仪的转轴进行找准。

C.1 测角仪

借助水平仪，通过两个可调支脚将测角仪调至水平。参照平面是准直仪支架的底盘。

C.2 自准直望远镜

在夹具中调整自准直望远镜（B2.2）以使旋转时目镜中水平十字线平行于转轴平面。您可以通过如下方式：

- * 在测角仪转台放置一个平行玻璃平晶（也可以用一个棱体）。
- * 通过转台（使用转台下面的螺丝（A2.10））将自准直望远镜就此平面找准。其自准直分划线的水平刻线位于目镜分划的双水平刻线之间。
- * 旋转旋臂，观察自准直图像如何变化。
- * 在旋臂旋转时注意自准直图像，一般来说，在目镜的双十字线上自准直图像将会出现垂直移动。请通过
在夹具中旋转自准直仪来修改它（图像设立）。

下一步，调整自准直仪的准直轴与旋转面平行：

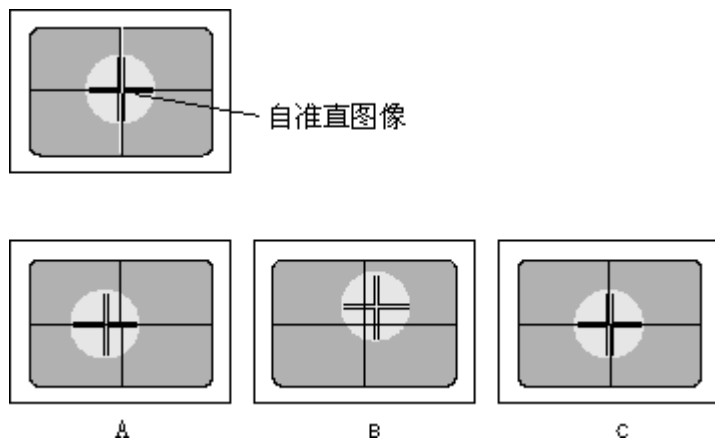
- * 将平行平晶放置于转台上并就自准直仪找准。然后将带有自准直仪的旋臂旋转 180° ，直到第二个表面的自准直图像出现。两个分划线的垂直位移必须相抵：一部分通过倾斜转台，另一部分通过调整螺丝倾斜实现。任何发生的小误差都必须通过重复上述步骤进行消除。

图 C1 显示自准直图像的定位：

单十字线：准直刻线的图像位置

双十字线：目镜刻线

图 F.1.C：显示自准直图像的正确调整



C.3 准直仪

你必须就自准直望远镜来调整准直仪（B1.4）。要保证准直刻线与自准直刻线重合。

- o 要在高度上倾斜，请使用调整螺丝（B1.3）。
- o 要调整图像设立，松开紧固螺丝（B1.2），轻微地旋转准直仪并再次将它固定。

请定期检查此项调整。

D 自动角度显示单元介绍

Heidenhain 控制板 IK220 (前向及后向计数器)

有关制造商 Dr. Johannes Heidenhain 的全套操作介绍收录在附录中。

通过与旋转分刻度盘相结合，与测角仪轴的“度盘”相连，该前向及后向计数器 IK220 是具有极高精度的角度显示单元。

测角仪 II 中的旋转度盘具有 36000 条刻线。

GonioWin 软件自动为控制板 IK220 进行所有必须的设定。如果不使用 GonioWin 软件，请参照 Heidenhain 手册中的指引，并使用 Heidenhain 的原装驱动。

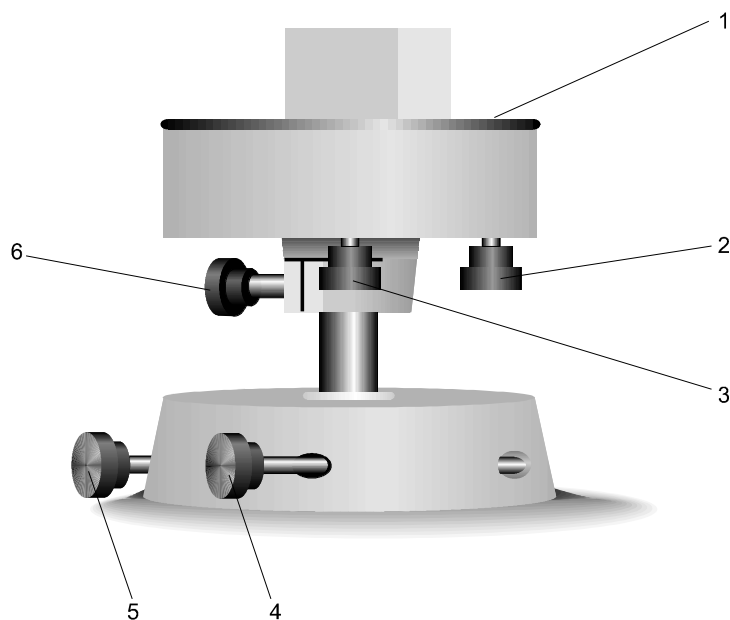
E 角度测量

E.1 棱体的找准

您需要将棱体的两个表面，（不是要测量的棱体角度），平行于仪器的转动轴。您可以借助自准直望远镜按如下方法进行：

- * 将棱体 放在棱体转台上，如图 E.2 所示。

图 E.1:



- 1 – 棱体的放置台面
- 2 – 用于可倾斜转台的调整螺丝
- 3 – 用于可倾斜转台的调整螺丝
- 4 – 锁定棱体转台的紧固螺丝
- 5 – 旋转棱体转台的精密调整螺丝
- 6 – 调整高度的紧固螺丝

- * 调整棱体的位置，以使光束尽可能的位于测量表面的中心。您可以借助一个白纸，如需要，调暗房间内的光线。

在旋松紧固螺丝（E1.6）后调整高度。如果是一个小的棱体，可能需要在棱体及棱体转台间放置一个平行玻璃平晶。
- * 通过最靠近自准直望远镜的调整螺丝（E1.2 及 E1.3）调整棱体转台，以找准棱体的表面。如果您没有看到双十字线的自准直图像，那么它可能超出了视场。
- * 旋转棱体转台，以找准第二个棱体表面。
- * 检查棱体的位置，如需要，再次调整。接上述方法找准棱体的表面。
- * 重复找准这两个表面，直到看不到双十字线的任何位移。

当然，只有当棱体可以充分反射时才能使用上述方法。

在一些情况下，光束也会从其它表面反射，因此在视场中可以同时看到几个反射图像。如果造成干扰的表面不是要测量的表面，那么你可以用不干胶纸贴上这个表面。

有时，您也可以临时、小心地向干扰的表面哈气，以使不需要的反射图像得到暂时消失。

E.2 测量棱体角度

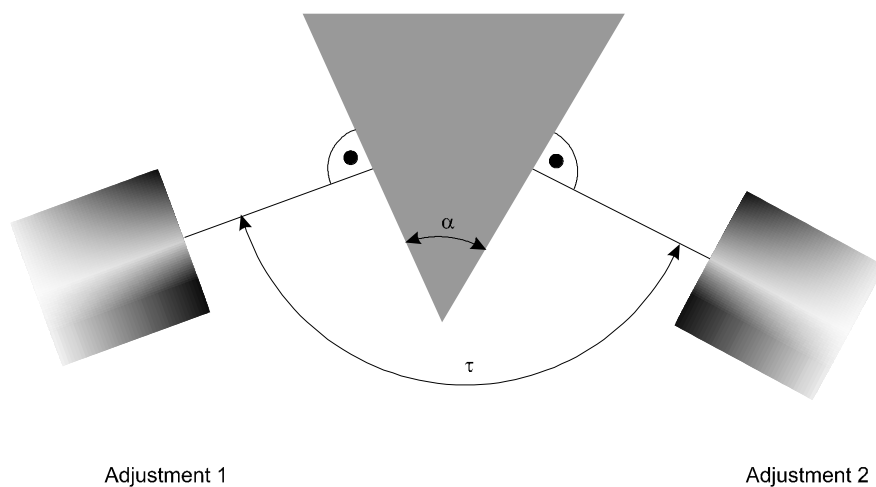
当棱体已经满意的置于中心并找准后，您需要进行下列步骤：

- * 通过旋臂的精调螺丝（A2.4）调整自准直望远镜与棱体的表面垂直。为此，双十字线的双垂直刻线须对称分布在目镜刻线的单线的两侧。
- * 读取角度显示单元的位置，并以相同方式将望远镜对准另一个棱体表面。
- * 从这两个读数中，您就可以以下列公式计算出棱体的角度 α （见图 E.2）：

测量角度 $\tau = \text{调整 2} - \text{调整 1}$

棱体角度 $\alpha = 180 - \tau$

图 E.2:



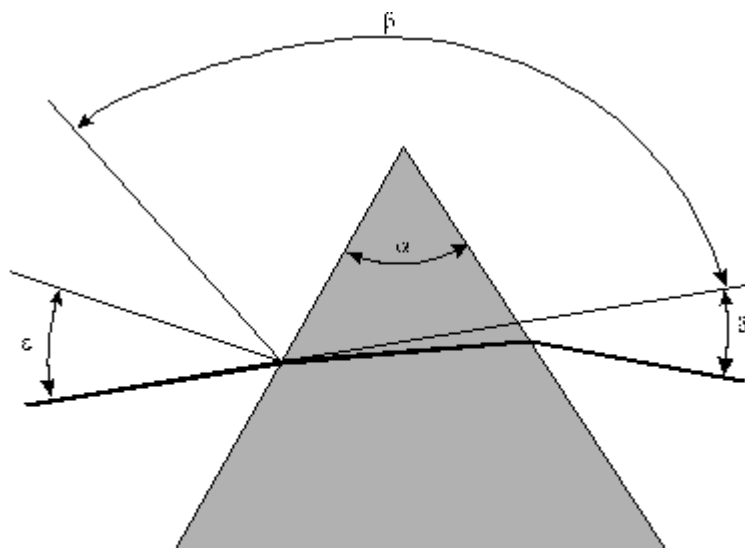
E.3 测量偏转角

当您把棱体就转运轴找准后，您可以进行进一步的测量：

- * 将棱体的入射面就准直仪的光束对称，并置于棱体转台上。
- * 检查棱体就转动轴的找准情况，如需要，接 E.1 章节重新调整。
- * 调整望远镜就物体狭缝的图像找准，并读出分划度盘上的位置。
- * 将棱体从光束中取出并测量未偏转的光束的位置。
- * 从这两个读数的差值中您就可以得出偏转角度。

为了提高测量精度，您需要在分划度盘的不同位置进行几次测量，并将不同的测量数值取平均值。

图.E.3 显示了角度的定义



α - 棱体角度

$$\beta = 180 - 2\epsilon$$

ϵ - 入射角

δ - 偏转角

F 光谱测量（选项一暂未翻译）

F.1 Introduction

The MÖLLER-WEDEL Goniometer II can be extended by means of the optionally available spectral equipment to form a spectrometer. This enables measurement of refractive indices of transparent glasses and liquids. Using a spectral lamp and slide-in filters, which permit selection of individual spectral lines, it is possible to determine refractive indices as a function of different wavelengths. Fig. F1 shows the Goniometer II with spectral equipment.

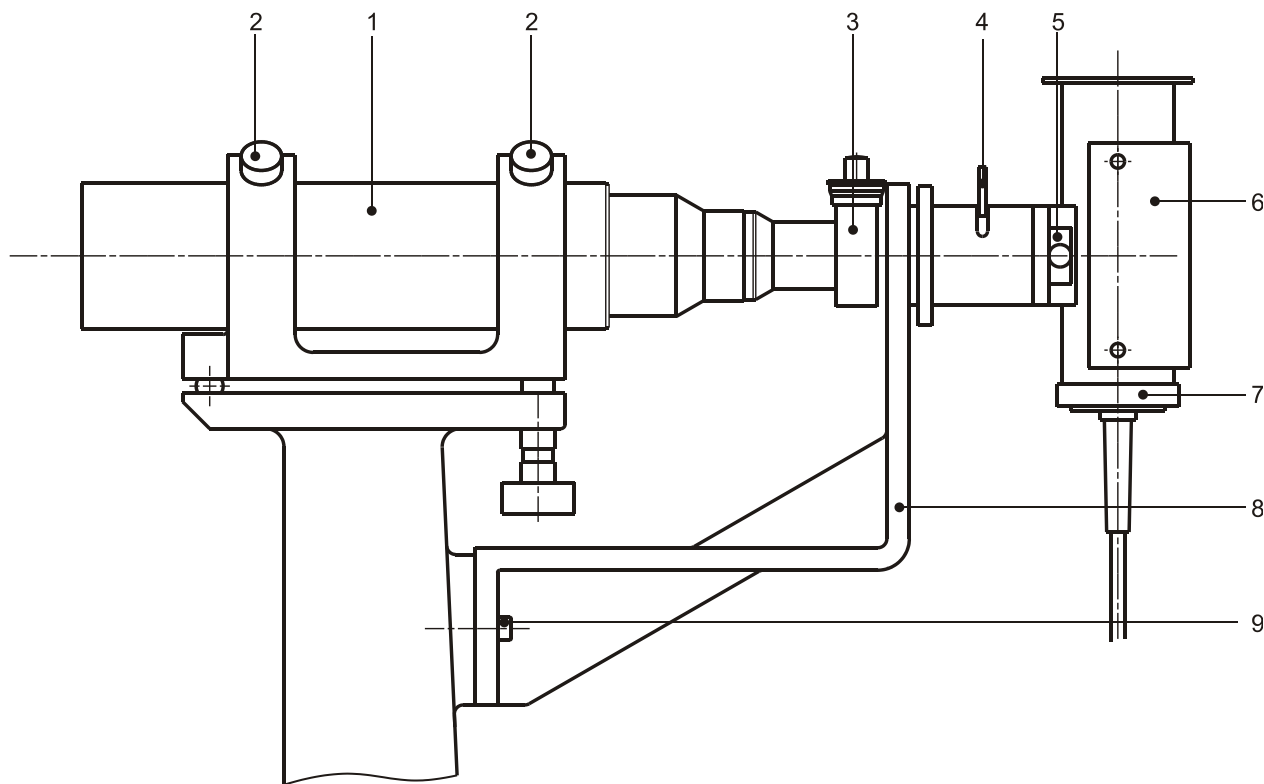


Fig. F1: Spectral illumination:

- 1 - Collimator tube
- 2 - Clamping screws
- 3 - Object slit (adjustable)
- 4 - Iris diaphragm
- 5 - Filter slide
- 6 - Lamp housing for spectral lamp
- 7 - Lamp holder, adjustable
- 8 - Holding bar
- 9 - Attachment screw

F.2 Description and assembly of the Spectral Illumination

The spectral illumination comprises the following components:

1. Holder for illumination unit (F1.8)
2. Adjustable precision slit (F1.3)
3. Iris diaphragm with brightness control (F1.4)
4. Lamp housing with spectral lamp (F1.6)
5. Filter slide (F1.5)
6. Power supply for spectral lamp (not shown)

F.2.1. Attachment of illumination unit

The spectral illumination unit is attached to the holding bar (F1.8) with the screw (F1.9) on the collimator stand of the goniometer.

The adjustable slit (F1.3) is attached to the collimator tube (F1.1) and factory-adjusted in such a way that it is precisely positioned in the rear focal plane of the collimator lens.

F.2.2. Insertion of spectral lamp

The inserted spectral lamp are commercially standard and must have a PICO 9 base.
A HgCd/10 spectral lamp is fitted as standard.

For insertion of the lamp, the lamp holder can be pulled downwards out of the housing (F1.6). For this purpose, unscrew the milled ring (F1.7).

When sliding the spectral lamp into the housing, make sure that the lamp is turned into a position where the discharge gap can illuminate the slit freely. Then secure the lamp holder with the milled ring (F1.7).

For adjustment of the beam path, there are three Allen screws positioned on the bottom of the lamp holder. These permit adjustment of the height and lateral position of the lamp.

F.2.3 Connection of spectral lamp

The spectral lamp is operated via a power supply (not shown).

The operating current for all lamps is 1.0 Ampere.
Before first-time operation of the power supply, check the settings of the mains voltage.

F.2.4. Adjustment of spectrometer slit (F1.3)

The adjustable object slit (3) can be aligned to the remote tube (F1.1) by turning the collimator tube after unscrewing the milled adjustment screws (F1.2).

F.2.5 Iris diaphragm (F1.4)

For regulation of the slit image luminous density, the beam flow can be set in the combined beam path with the iris diaphragm (4).

F.2.6 Filter slide (F1.5)

Filters can be inserted in the illumination beam path for separation of the spectral lines emitted by the spectral lamp. The standard version of the filter slide is fitted with 3 filters and also have on further free opening.

F.3 Adjustment of the illumination unit

You have to adjust the illumination unit in such a way, that the iris diaphragm is positioned symmetrically to the optical axis.

Check this for instance with a white sheet of paper in front of the collimator. The spot has to be concentric to the collimator aperture, when stopping down the iris diaphragm or the height of the object slit.

Find a uniform illuminating object slit with the aid of the adjustment screws. Sometimes a turning of the spectral lamp gives a good result.

F.4 Adjustment of the slit width

The basic adjustment of the Goniometer (Operation Manual Section C) must be made before the following steps are taken.

- * Align the collimator to the autocollimation telescope.
- * Align the object slit to the eyepiece reticle .
- * Slide the 546 nm interference filter in.
- * Set the slit width to an appropriate value.

Chose an adequate slit width, which is small enough to resolve the wanted spectral lines. You get the highest reading accuracy with an eyepiece, if the ratio of slit width to hair line width is about 1:0.6. If you use a CCD camera this ratio decreases.

- * Align the telescope
precisely to the collimator (in collimation) , using the fine adjustment knob of the swivel arm;
note the angular position of the graduated circle.

F.5 Making a measurement

Release clamping of prism table.

1. Align the prism table such that its optically effective surfaces are positioned opposite the adjustment screws of the table (Fig. F2)
2. Slide filter out of the beam (Fig. F3)
3. Find the minimum deflection (symmetrical beam path) of the prism (Fig. F4). For this purpose, turn the prism with respect to the collimator such that the beam passes through the prism at the two optically effective surfaces.
4. Slide in filter (preferably 546 nm)
5. Slowly turn the prism and follow the slit image with the telescope. Continue doing this until the observed slit image moves in the opposite direction.
Then set the reversal point (minimum deflection). This setting must be made with the greatest possible accuracy.
6. To check the alignment of the prism, slide the filter out of the beam path. It is convenient to check the illumination of the prism surface by means of a light-colored piece of paper, which is held up in front of the prism surface. With smaller prisms, the collimator lens should be stopped down (iris diaphragm or simply a fixed diaphragm made of card). The aim is to achieve symmetrical illumination of the prism surface.
7. The two refractive surfaces of the prism must be aligned parallel to the axis of rotation of the goniometer. This is done by means of autocollimation.
8. Switch on the illumination of the autocollimation ocular on the telescope. Align the telescope to a refractive prism surface and set to autocollimation. Align the prism with the aid of the adjustment screws on the prism table in such a way that the horizontal line of the autocollimation image (reflected beam pencil) is within the double line of the eyepiece reticle.
9. Repeat the operation described under item 8. above at the second refractive surface of the prism.
10. In order to check this, set the autocollimation image of the first surface again; if necessary adjust the prism again. Repeat the operations described under items 8 and 9 if necessary until the two prism surfaces are aligned parallel to the axis of rotation.
11. As described under item 6, find the minimum deflection and fix the prism table. Use the fine adjustment screw to find the exact minimum of deflection.
12. Align the telescope exactly to spectrometer lit.
13. The deflection angle δ (Fig. F4) can be read-off directly by using the GONIOWIN software. In addition, the angle can easily be calculated from the two absolute readings.

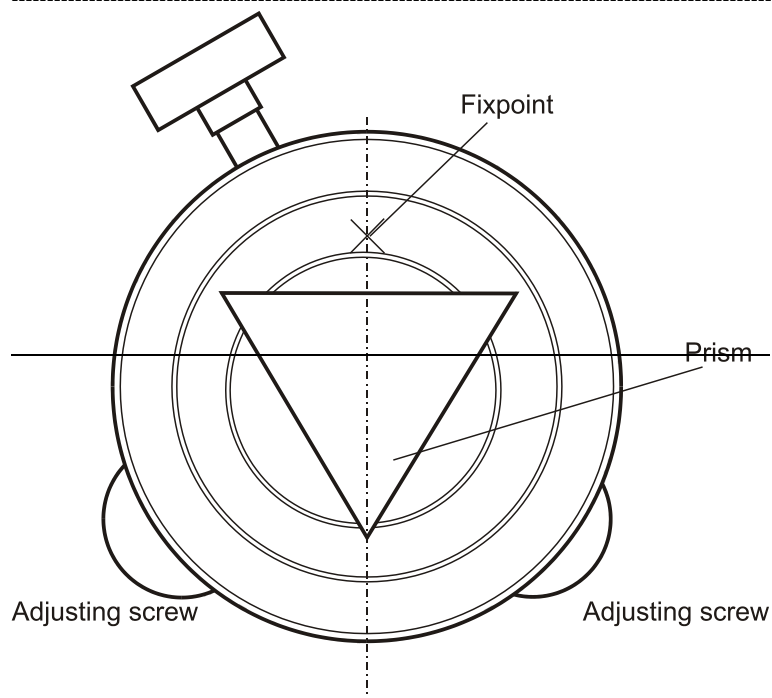


Figure F2: Setting the dispersion prism on prism table

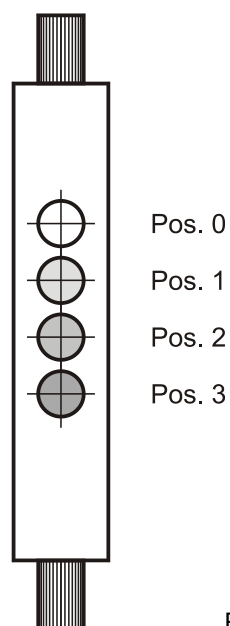


Figure F3: Filter slide

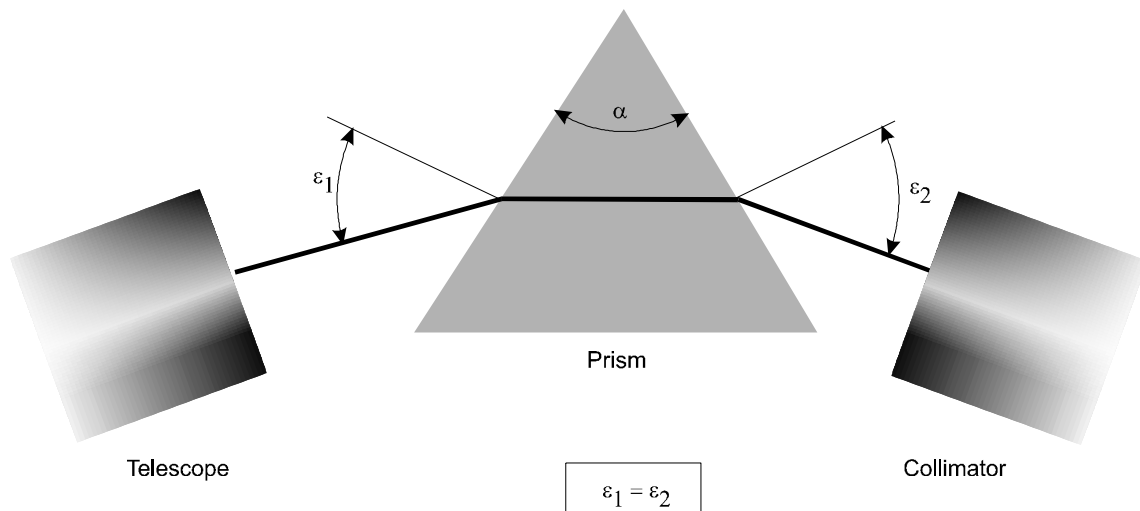
F.6 Measurements and calculations

F.6.1 Fraunhofer's method

Measurement

The method described here for determination of refractive indices of optical glasses or optical transparent materials are derived from J. Fraunhofer (1817). This is called the minimum deviation method (Fig.F.4).

Fig.F.4)



You have to measure the angle of deviation δ (Fig.F.4) as a function of wavelength for the minimum deviation.

1. Turn the swivelling arm in the position, where the optical axis of autocollimation telescope and collimator coincide (0-position) .
2. Set the digital counter of the incremental circle to zero
3. Slide filter out of the beam path
4. Release the clamps of the prism table
5. Align the prism on the prism table
- * Position the optically effective surfaces opposite to the adjustment screws of the table (Fig. E1) .
- * Check the illumination of the prism.

For this it is convenient to use a white sheet of paper, which is held up in front of the prism surface. With smaller prisms, the collimator lens should be stopped down (by fixing an iris diaphragm or simply card diaphragm) . The aim is to achieve symmetrical illumination of the prism surface.

- * Align the two refractive surfaces of the prism parallel to the axis of rotation of the goniometer by autocollimation.

Switch the illumination of the autocollimation telescope on.

Align the telescope to a refractive prism surface and set to autocollimation.

Align the prism with the aid of adjustment screws on the prism table in such a way that the horizontal line of the eyepiece reticle is within the double line of the autocollimation image (reflected pencil-beam) .

Repeat the operation for the second refractive surface of the prism.

Check the alignment of the first refractive surface, if necessary adjust the prism again .

Repeat the operation described above as often as necessary to get both prism surfaces aligned parallel to the axis of rotation.

- * Align the telescope exactly to the spectrometer slit

6. Slide the filter (preferably 546 nm) in.
7. Find the minimum deviation (symmetrical beam path)
 - * Turn the prism in such a way, that the beam passes through the two polished surfaces.
 - * Use the telescope (or first with the naked eye) to find the deviated beam pencil.
 - * Turn the prism slowly and follow the slit image with the telescope until the image moves in the opposite direction.

Use the fine adjustment screw (A2.4 and A2.13) to find the exact minimum of deviation.

Pin-point this setting with the greatest possible accuracy!

- * Fix the reversal point (minimum deflection)
8. Read out the deflection angle δ

If you have set the counter to zero when setting up (see item 2) you can do it directly. Otherwise you have to calculate the angle from the two absolute values.

For a more accurate determination of the refractive index, you can also determine the minimum of deviation for the other direction and calculate the mean value from the two readings.
 9. For the next wavelength slide in the right filter and repeat from item 6.

Calculation of the refractive index

In order to calculate the refractive index, you must know the prism angle α .
You can calculate the refractive index for the specific wavelength as follows:

$$(1) \quad n = \frac{\sin (0.5 (\delta_{\min} + \alpha))}{\sin (0.5 \alpha)}$$

$\delta_{\min}$: minimum deviation angle
 α : prism angle

In section I2, you will find a table of usable spectral lines.

F.6.2 Rudberg's method

If you have to measure the refractive indices for a large number of spectral lines, Rudberg's extension of Fraunhofer's method offers the advantage that the observation time is considerably shorter. There is however a more complicated and longer calculation to be carried out after measurement. This method is always used, particularly with dispersion measurements, if a sufficiently constant observation room temperature cannot be guaranteed.

* Set up the prism so that a beam of medium wavelength of the required range passes through it with minimum deviation (see chapter F.3.1, items 1-6) .

* Calculate the angle of incidence ε (see Fig. E.3)

Turn the swivelling arm to find the slit image of the reflected beam of the prism surface. Now read out the angle β , which is $180^\circ - 2\varepsilon$. You get:

$$\varepsilon = \frac{1}{2} (180^\circ - \beta)$$

* Adjust the telescope in succession to all required spectral lines k to measure the deviation angles $\delta_1 \dots \delta_k$ of the through position of the slit image. Please note, you have to fix the angle of incidence ε for all spectral lines!

* Obtain the refractive indices from:

$$n = \frac{\sin \varepsilon}{\sin \varepsilon_k'}$$

with:

$$\tan (\varepsilon_k' - \alpha/2) = \frac{\tan (\alpha/2) \tan (\varepsilon - 1/2 (\delta_k + \alpha))}{\tan (1/2 (\delta_k + \alpha))}$$

To increase precision, the measurements are repeated at the other side of the prism after adjustment the object stage accordingly, in order to measure the doubled angle of deflection.

Using the angle of minimum deviation you can calculate the angle of incidence ε with the equation:

$$(2) \quad \varepsilon = (\alpha + \delta_{\min}) / 2$$

For your measurements you need the angle β (Fig. I.3), where:

$$(3) \quad \beta = 180^\circ - 2\varepsilon$$

G 误差分析（折射率测量—暂未翻译）

G.1 Influence of individual errors on the precision of measurements of the refractive indices

We shall now briefly discuss the most important errors which can occur and which you have to take into account in making accurate measurements of the refractive index. Most of the data are obtained from the work of L.W. Tilton [Tilton], who made a particularly thorough study of the various possible errors.

He relates to the method of minimum deviation, but it can naturally also be applied accordingly to the Rudberg method.

The newest publication known, is the work of Tentori et al. [Tentori90].

The most favourable prism angle is given about 60° (for details see table next 页), for the liquid measurements with hollow prisms of 72° .

Tentori,D., Lerma,J.R. Optical Engineering 29 (1990) ,160
Tilton,L.W. Bur. Stand. J.Res.2 (1929) ,909-930
Tilton,L.W. Bur. Stand. J.Res.6 (1931) ,52-76
Tilton,L.W. Bur. Stand. J.Res.11 (1933) ,25-57
Tilton,L.W. Bur. Stand. J.Res.13 (1934) ,111-124
Tilton,L.W. Bur. Stand. J.Res.14 (1935) ,393-418
Tilton,L.W., Taylor,J.K. Bur. Stand. J.Res.20 (1938) ,419-477

The following table indicates the tolerances on angle measurements, which results in a probable error of $\pm 1 \times 10^{-6}$ in refractive index.

Refractive index	1.3	1.5	1.7	1.9
Optimum prism angle	75°	67°	61°	56°
Radius of curvature of prism surface with lateral displacement of 0.2 mm	170 m	350 m	570 m	1100 m
Prism angle	$\pm 0.57''$	$\pm 0.33''$	$\pm 0.22''$	$\pm 0.16''$
Double angle of deflection	$\pm 0.82''$			
Minimum adjustment of prism	$\pm 3.6'$	$\pm 3.1'$	$\pm 2.7'$	$\pm 2.4'$

A lateral displacement of the prism of 0.2 mm in relation to the optical axis of the telescope and a radius of curvature which for $n=1.3$ to 1.9 is between 170 and 1100 m, the probable error of the calculated refractive indices amounts to $\pm 1 \times 10^{-6}$.

Measurements of the double angle of deviation need not generally be carried out with the same accuracy as measurements of the prism angle.

In spite of the relatively wide tolerance, prism adjustment to minimum deviation must be executed carefully, since the error is always unilaterally positive.

Correction of minimum adjustment is only necessary for particular measurements.

G.2 Errors depending on test conditions

With the Goniometer-Spectrometer II you measure the relative refractive index n of a transparent medium in air. The main influence on test conditions except the wavelength come from:

- Prism temperature
- Air temperature
- Air pressure
- Air humidity

You can separate the relative refractive index of the prism in an absolute refractive index of the prism n_{abs} and of the air n_L by the formula:

$$n_{\text{abs}} = n \times n_L$$

The temperature coefficient of the absolute refractive index of glass has values in a range of:

$$-10 \times 10^{-6} < (\Delta n / \Delta t)_{\text{abs}} < 20 \times 10^{-6} / ^\circ\text{C}$$

It depends on the prism temperature and the wavelength.

- The temperature influence varies strongly with the glass.
- With a decrease of wavelength the temperature coefficient increases.

Example: Change of absolute refractive index in units of 10^{-6} ,
Temperature :20 °C, temperature increase 1°C

	644 nm (C')	436 nm (g)
Synthetic fused silica	9.7	10.5
Schott glass FK52	-8.0	-7.5
Schott glass K5	0	0.9
Schott glass SF6	7.3	14.0

The temperature coefficients of liquids are particularly high.

G.3 Correction of the refractive index

You can correct the relative refractive index on reference conditions. The normal conditions are customary:

- Temperature of glass and air $t_0 = 20^\circ\text{C}$
- Pressure of air $p_0 = 1023 \text{ mbar}$
- Humidity of air $e_0 = 13.3 \text{ mbar}$ (50% rel. humid.)

The corrected relative refractive index n_K is given by:

$$n_K = n + \Delta n$$

where Δn is the total differential:

$$\Delta n = \Delta t x \frac{\partial n}{\partial t} + \Delta p x \frac{\partial n}{\partial p} + \Delta e x \frac{\partial n}{\partial e}$$

with $\Delta t = t - t_0$, $\Delta p = p - p_0$, $\Delta e = e - e_0$.

If you use the formula $n_{\text{abs}} = n \times n_L$, you get partial differentials of the absolute refractive index of the air n_L and of the prism n_{abs} . To solve the partial differentials of the absolute refractive index of air, you can use the „Edlen Formular“ [Edlen66, Owens 67, Jones81, Meiser 89]. This formular gives the refractive index of air as a function of wavelength, temperature, pressure and humidity. It is accurate to 10^{-8} for a temperature range of 5-30°C, a pressure range from 0-1067mbar and a wavelength range from the near UV to the near IR.

Edlen, B. Metrologia 2 (2), (1966) 12

Owens, J.C. Applied Optics 6 (1967) 51

Jones, F.E. J. of Research of the Nat. Bur. of Stand. 86 No.1, (1981) 27

Meiser, H.P., Luhs, W., Frerking, D. VDI Berichte 749 (1989) 107

The corrected relative refractive index is:

$$n_k = n_m \left\{ 1 - \Delta t \frac{1}{n_m} \left[\frac{\Delta n_{abs}}{\Delta t_{abs}} - \frac{\partial n_L}{\partial t} \right] - \Delta p \frac{\partial n_L}{\partial p} - \Delta e \frac{\partial n_L}{\partial e} \right\}$$

with $\Delta t = t - t_0$, $\Delta p = p - p_0$, $\Delta e = e - e_0$.

QUANTITIES:	MEASUREMENT:	REFERENCE:
• relative refractive index	n_m	n_k
• temperature of air, prism in °C	t	t_0
• air pressure in mbar	p	p_0
• air humidity in mbar	e	e_0

normal conditions: $t_0 = 20\text{ °C}$, $p_0 = 1013.25\text{ mbar}$, $e_0 = 13.3\text{ mbar}$

The partial differentials evaluated from the Edlen-Formel are:

$$\frac{n_L}{t} = -(n_L - 1) \times 3.82 \times 10^{-6} \times \frac{p}{(1 + 3.67 \times 10^{-3} \times t)^2}$$

$$\frac{n_L}{p} = (n_L - 1) \times 1.04 \times 10^{-3} \times \frac{1}{1 + 3.67 \times 10^{-3} \times t}$$

$$\frac{n_L}{e} = -(4.292 - \frac{0.0343}{\lambda^{-2}}) \times 10^{-8}$$

$$n_L - 1 = 8.3421 \times 10^{-5} + \frac{2.40603 \times 10^{-2}}{130 + \lambda^{-2}} + \frac{1.5997 \times 10^{-4}}{38.9 + \lambda^{-2}}$$

$(n/t)_{abs}$: absolute temperature coefficient of the medium

λ : wavelength in μm

G.4 Sensitivity Analysis

The relative refractive index correction n can be separated in amounts of prism and air as the following formula shows:

$$\Delta n = n_k - n = \underbrace{-t \left(\frac{\Delta n}{\Delta t} \right)_{abs}}_{\text{prism}} - \underbrace{n \chi \Delta t \frac{\partial n_L}{\partial t} - \Delta p \frac{\partial n_L}{\partial p} - \Delta e \frac{\partial n_L}{\partial e}}_{\text{air}}$$

Sketch: Correction of relative refractive index as a function of temperature coefficient of glass

$$\lambda = 546 \text{ nm}$$

$$t = 20^\circ\text{C} \quad \pm 1^\circ\text{C}$$

$$p = 1013.25 \text{ mbar} \quad \pm 1 \text{ mbar}$$

$$e = 13.3 \text{ mbar} \quad \pm 3 \text{ mbar}$$

H 仪器的维护

H1. 清洁抛光表面

- o 避免用手接触任何抛光的部件，包括透镜、棱体、玻璃平晶及反射镜的反射面。
- o 光学表面的任何灰尘应当用精细的毛刷清洁。
- o 如果光学表面受污较严重，您需要用一支蘸有 6 倍乙烯:1 倍酒精溶剂的棉球棒来清除。

当心：这些溶剂是易燃的！

- o 我们备有全套清洁工具可供选购（订货号：241 146）

H2. 角度显示单元

它不需要特别的维护。

I 技术数据

I.1 规格

测角仪 II

o	尺寸	
-	长/宽/高	760 x 360 x 640 mm
-	带有光谱光源单元	1070x360x670mm
-	需要台面最小尺寸	800x350mm
-	旋臂半径	300 mm
-	棱体转台直径	135 mm
-	准直仪与望远镜间的最大距离	158 mm
o	重量	约 80 kg

玻璃分划度盘

o	2 个电子读数测头，呈 180°分布	
o	光学调整	
o	光电角度测量，带有电子信号评估	
o	刻线	36000 线
o	显示步进	0.0001°
	可调至	1 秒/0.1 秒/（0.036 秒显示分辨率）
o	工作范围	360°
o	精度	
-	单次测量	优于 3"
-	连续测量	优于 0.6"
o	结果评估	
	显示	计算机显示器/带有 IK220 控制器的计算机
-	评估	自动
	计算机辅助	通过 GonioWin 软件

准直仪

o	物镜:	玻璃元件, 消色差
-	镀膜	AR 镀膜
-	面形误差	$< \lambda/5$ p-v
-	焦距	300 mm
-	自由孔径	50 mm

望远镜及探测器

o	物镜	玻璃元件, 消色差
-	镀膜	AR 镀膜
-	面形误差	$< \lambda/5$ p-v
-	焦距	300 mm
-	自由孔径	50 mm
o	光源	6V/5W
o	分划:	双十字线/单十字线
o	目镜	
-	焦距	14.7 mm

I.2. 折射率波长表

波长 [nm]	符号	元件
2325.4		Hg
1970.1		Hg
1529.6		Hg
1014	t	Hg
852.1	s	Cs
706.5	r	He
656.3	C	H
643.8	C'	Cd
587.6	d	He
546.0	e	Hg
486.0	F	H
480.0	F'	Cd
435.8	g	Hg
404.6	h	Hg
365.0	i	Hg
253.6		Hg

J. 照片



图 J1: Heidenhain 传感器至控制板 IK220 的电缆连接

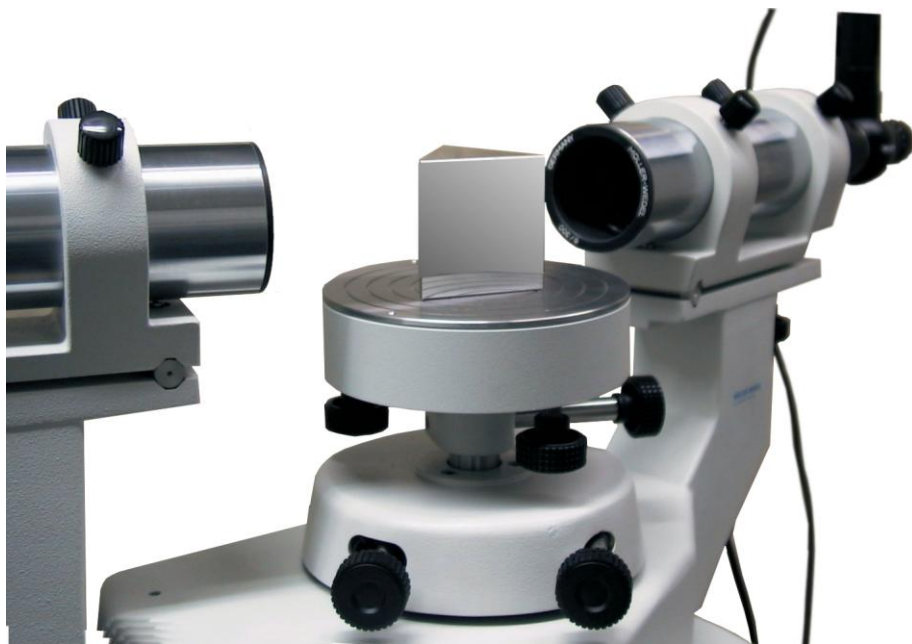


图 J2: 棱镜转台