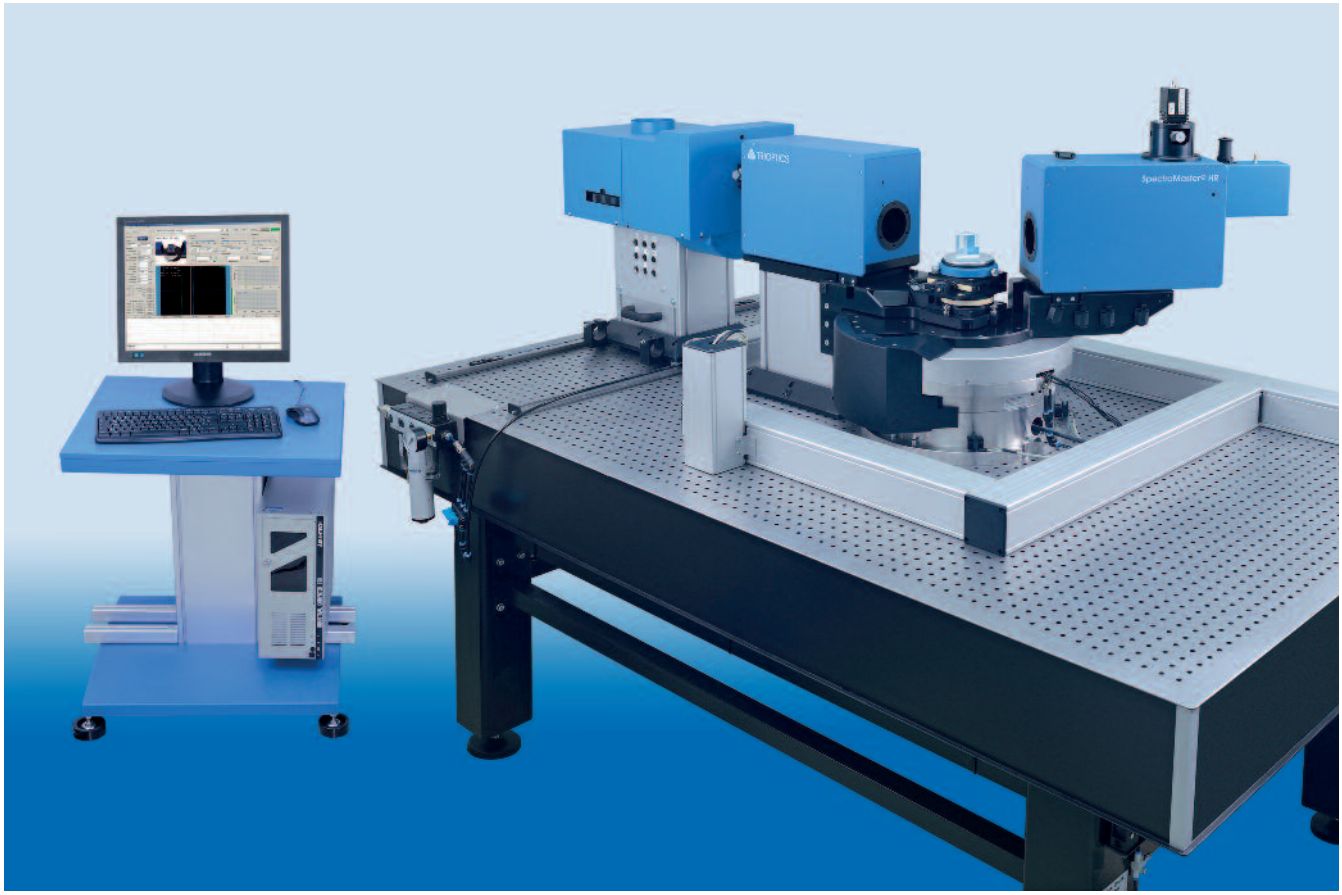
TRIOPTICS

TRIOPTICS GMBH · OPTICAL TEST EQUIPMENT

SpectroMaster®

High Precision Automatic Spectrometer-Goniometer



TRIOPTICS

TRIOPTICS GMBH · OPTICAL TEST EQUIPMENT

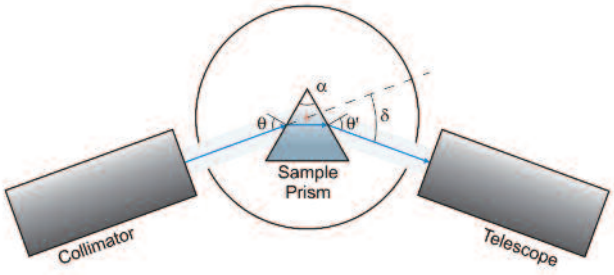
CONTENTS

Overview

The SpectroMaster® family of instruments has been derived from the renowned TRIOPTICS PrismMaster® series of ultra-accurate prism goniometers and is specifically designed for prism refractometry with highest precision. SpectroMaster® Spectrometer-Goniometers are employed by optical glass manufacturers, national metrology institutes as well as scientific research institutes with highest accuracy demands for the determination of the refractive index and dispersion of optical glass and crystalline materials in the UV, VIS or IR spectral range.

The measurement principle is based on the minimum deviation method, originally published by Joseph von Fraunhofer almost 200 years ago and still regarded as the most accurate method and capable to measure the refractive index up to the sixth decimal place. It is therefore the standard method employed by most national metrology institutes e.g. the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig, Germany. The core of SpectroMaster® is an ultra-high precision goniometer table, which is used for measuring the prism angle and the deviation angle of refracted light passing through a prism manufactured from the optical material under test. The large spectral range of the high-end SpectroMaster® models is obtained by the complete use of mirror optics. For a more limited visible spectral range, models with refractive optics are available, too.

Measurement Principle



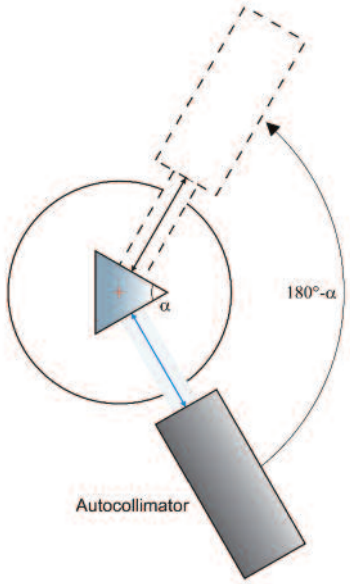
Measurement principle of deviation angle

The minimum deviation method as described by Fraunhofer at the beginning of the 19th century is sketched above. It is based on the refraction of light by a precise prism manufactured from the optical material under investigation. A bundle of monochromatic collimated light from a collimator enters at one surface of the prism and is refracted at a certain deviation angle δ when leaving the second surface. The deviation angle is a function of the wavelength λ and is measured by a telescope attached to a goniometer table. The angle enclosed by the two prism surfaces is generally called the apex angle α of the prism. When the incidence angle θ at which the light enters the prism is changed, the deviation angle δ changes too. It can be shown that the deviation angle δ becomes minimal when the angle θ' at which the beam leaves the second surface is equal to θ, i.e. $\theta = \theta'$. This symmetric case is the so-called minimum deviation condition. In this case, the index of refraction of the prism material can be calculated according to

$$n(\lambda) = \frac{\sin\left(\frac{\alpha + \delta(\lambda)}{2}\right)}{\sin\left(\frac{\alpha}{2}\right)} \times n_{\text{air}}(\lambda, p, T),$$

where n_{air} is the refractive index of the ambient air. n_{air} is a function of the wavelength λ, temperature T, pressure p and

humidity and can be calculated with sufficient accuracy from p and T with the generally approved Edlén equation. In most cases, the humidity can be neglected. Since these calculations are quite complex and error-prone, this is done automatically by the instrument software.



Apex angle measurement principle

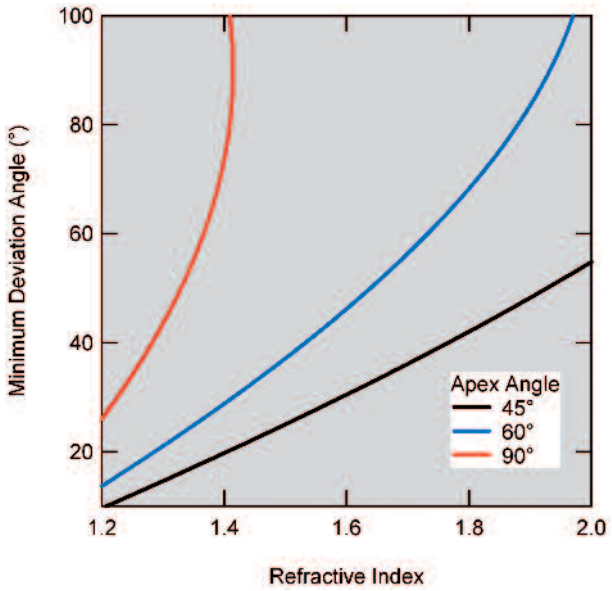
The refractive index can be determined only when the apex angle α is precisely known. Both angles α and δ are measured with an ultra-precision goniometer with sub-arcsecond accuracy. The apex angle α is measured with an autocollimator attached to the goniometer table.

Error Analysis and System Requirements

For reaching an accuracy down to 1×10^{-6} a careful error analysis of the above formula is necessary from which the technical requirements on both instrument and ambient conditions can be derived. In the following, it is distinguished between errors resulting from the goniometer, errors due to ambient conditions, and errors due to the manufacturing quality of the sample.

Goniometer Error

As shown above, the refractive index measurement is based on angle measurements. This is done by a precision goniometer equipped with an autocollimation telescope for measuring both the apex angle α and the minimum deviation angle δ. The figure below shows the dependence of the minimum deviation angle on the sample refractive index and apex angle. For typical optical glass, prisms with an apex angle of around 60° are used. The samples with a refractive index ranging from $n = 1.2 \ldots 2.0$ cause minimum deviation angles of about 15° to 100°. The impact of errors in both apex and minimum deviation angle on the refractive index result are compiled in the following table, calculated for standard ambient conditions.



Minimum Deviation Angle vs. Refractive Index for different prism apex angles

From this result it becomes evident that the angle measurement must be accurate to a fraction of an arc second if an accuracy of about 1×10^{-6} is required.

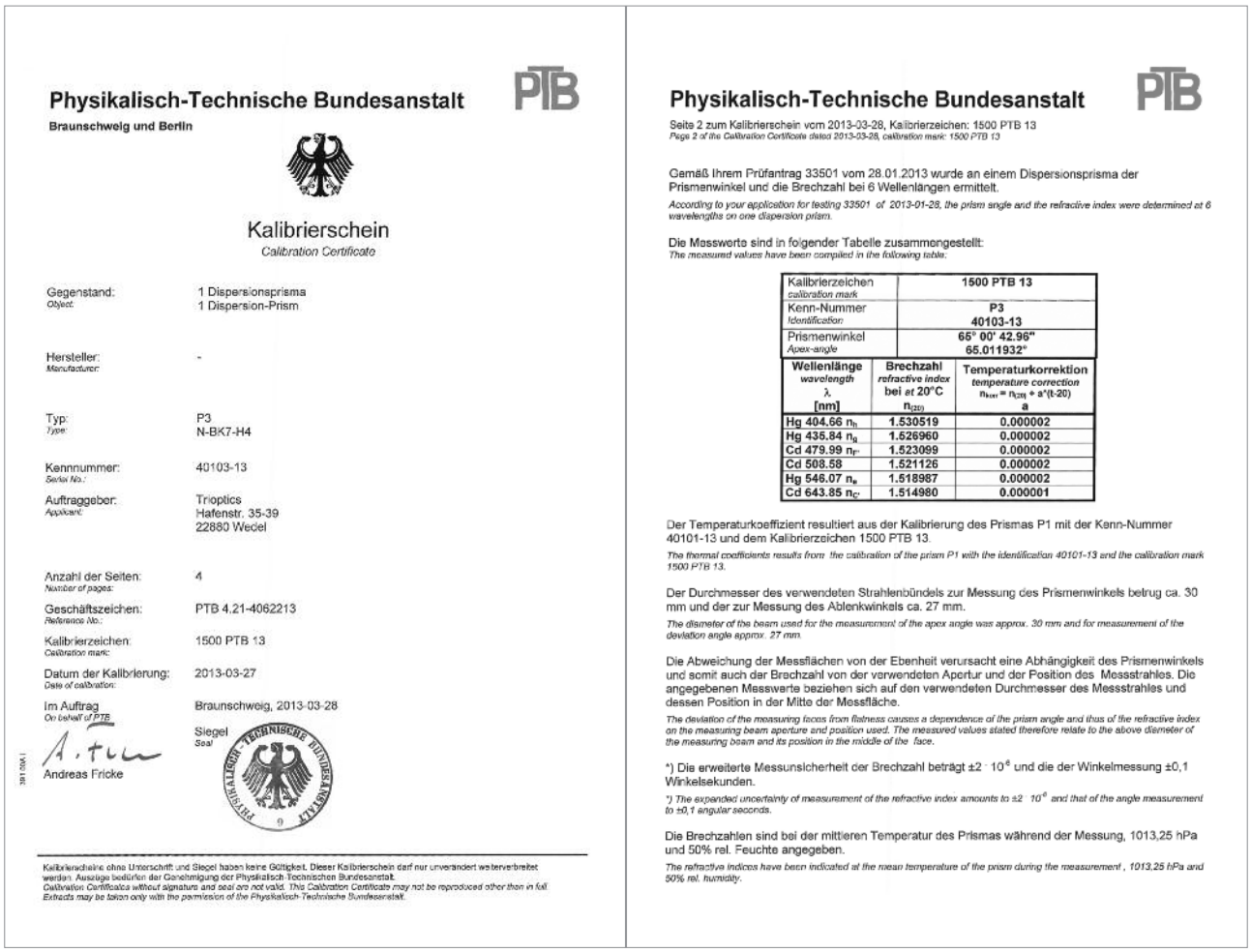
TRIOPTICS has a long experience in manufacturing prism goniometers measuring at

this level of accuracy. The goniometers of the TRIOPTICS PrismMaster® HR ultra accuracy class are equipped with specially selected Heidenhain goniometers of the highest accuracy available. With these precision goniometers and a special eccentricity and interpolation error compeation, an angle measurement uncertainty of less than ±0.1 arcsec at a resolution of 0.036 arcsec can be achieved.

The SpectroMaster® angle measurement is a combined effort of the goniometer assuring the precise angle measurement over large angles and an electronic autocollimator for small differential angle measurements. The autocollimator is used for precisely relating the prism surface orientation to the graduated circle of the goniometer.

High precision optics and high-resolution CCD cameras guarantee a linearity and resolution to about 1/100 arcsec.

The overall angle measurement accuracy is carefully checked at the TRIOPTICS laboratory with several reference samples which have been measured and certified with ±0.1 arcsec uncertainty (k=2) by the Physikalisch-Technische Bundesanstalt (PTB), the German national institute of standards and metrology. At TRIOPTICS, the PTB results are typically reproduced within ±0.1 arcsec maximum deviation when measured with ultra-precision class goniometers. The results are directly traceable to national and international angle standards.



Physikalisch-Technische Bundesanstalt

Braunschweig und Berlin

PTB

Kalibrierschein

Calibration Certificate

Gegenstand: *Object:*	1 Dispersionsprisma 1 Dispersion-Prism
Hersteller: *Manufacturer:*	-
Typ: *Type:*	P3 N-BK7-H4
Kennnummer: *Serial No.:*	40103-13
Auftraggeber: *Applicant:*	Trioptics Hafenstr. 35-39 22880 Wedel
Anzahl der Seiten: *Number of pages:*	4
Geschäftszeichen: *Reference No.:*	PTB 4.21-4062213
Kalibrierzeichen: *Calibration mark:*	1500 PTB 13
Datum der Kalibrierung: *Date of calibration:*	2013-03-27
Im Auftrag *On behalf of PTB*	Braunschweig, 2013-03-28

Andreas Fricke

Siegel *Seal*

Kalibrierscheine ohne Unterschrift und Siegel haben keine Gültigkeit. Dieser Kalibrierschein darf nur unverändert weiterverbreitet werden. Auszüge bedürfen der Genehmigung der Physikalisch-Technischen Bundesanstalt.
Calibration Certificates without signature and seal are not valid. This Calibration Certificate may not be reproduced other than in full. Extracts may be taken only with the permission of the Physikalisch-Technische Bundesanstalt.

Physikalisch-Technische Bundesanstalt

PTB

Seite 2 zum Kalibrierschein vom 2013-03-28, Kalibrierzeichen: 1500 PTB 13
Page 2 of the Calibration Certificate dated 2013-03-28, calibration mark: 1500 PTB 13

Gemäß Ihrem Prüfantrag 33501 vom 28.01.2013 wurde an einem Dispersionsprisma der Prismenwinkel und die Brechzahl bei 6 Wellenlängen ermittelt.

According to your application for testing 33501 of 2013-01-28, the prism angle and the refractive index were determined at 6 wavelengths on one dispersion prism.

Die Messwerte sind in folgender Tabelle zusammengestellt:
The measured values have been compiled in the following table:

Kalibrierzeichen *calibration mark*	1500 PTB 13	
Kenn-Nummer *identification*	P3 40103-13	
Prismenwinkel *Apex-angle*	65° 00' 42.96" 65.011932°	
Wellenlänge *wavelength* λ [nm]	**Brechzahl** *refractive index* bei *at* 20°C $n_{(20)}$	**Temperaturkorrektion** *temperature correction* $n_{(t)} = n_{(20)} + a*(t-20)$ a
Hg 404.66 n_h	1.530519	0.000002
Hg 435.84 n_g	1.526960	0.000002
Cd 479.99 $n_{F'}$	1.523099	0.000002
Cd 508.58	1.521126	0.000002
Hg 546.07 n_e	1.518987	0.000002
Cd 643.85 $n_{C'}$	1.514980	0.000001

Der Temperaturkoeffizient resultiert aus der Kalibrierung des Prismas P1 mit der Kenn-Nummer 40101-13 und dem Kalibrierzeichen 1500 PTB 13.

The thermal coefficients results from the calibration of the prism P1 with the identification 40101-13 and the calibration mark 1500 PTB 13.

Der Durchmesser des verwendeten Strahlenbündels zur Messung des Prismenwinkels betrug ca. 30 mm und der zur Messung des Ablenkwinkels ca. 27 mm.

The diameter of the beam used for the measurement of the apex angle was approx. 30 mm and for measurement of the deviation angle approx. 27 mm.

Die Abweichung der Messflächen von der Ebenheit verursacht eine Abhängigkeit des Prismenwinkels und somit auch der Brechzahl von der verwendeten Apertur und der Position des Messstrahles. Die angegebenen Messwerte beziehen sich auf den verwendeten Durchmesser des Messstrahles und dessen Position in der Mitte der Messfläche.

The deviation of the measuring faces from flatness causes a dependence of the prism angle and thus of the refractive index on the measuring beam aperture and position used. The measured values stated therefore relate to the above diameter of the measuring beam and its position in the middle of the face.

*) Die erweiterte Messunsicherheit der Brechzahl beträgt ±2 · 10^{-6} und die der Winkelmessung ±0,1 Winkelsekunden.

*) *The expanded uncertainty of measurement of the refractive index amounts to ±2 · 10^{-6} and that of the angle measurement to ±0,1 angular seconds.*

Die Brechzahlen sind bei der mittleren Temperatur des Prismas während der Messung, 1013,25 hPa und 50% rel. Feuchte angegeben.

The refractive indices have been indicated at the mean temperature of the prism during the measurement , 1013,25 hPa and 50% rel. humidity.

PTB measurement certificate for a dispersion prism

Additionally, the SpectroMaster® measurement procedures are performed in a way as to minimize systematic errors and ambient influences, e.g. all angle measurements are done differentially on both sides of the prism, so that potential offset errors are removed by calculating angle differences only. Furthermore, noise is reduced since all angle results emerge from at least two measurements. For further noise reduction, the system can be configured to perform even more measurements for better averaging. However, the experience shows that in a well-shielded environment noise shows up in the 7th decimal place of the refractive index result only.

Ambient Conditions

As stated above, carefully controlled ambient conditions are required since the measurement quantities depend on the ambient and sample temperature and air pressure. In standard laboratories the air pressure cannot be controlled, but must be taken into account by calculation. This is accurate enough when the air pressure is known with a precision of at least 1 hPa.

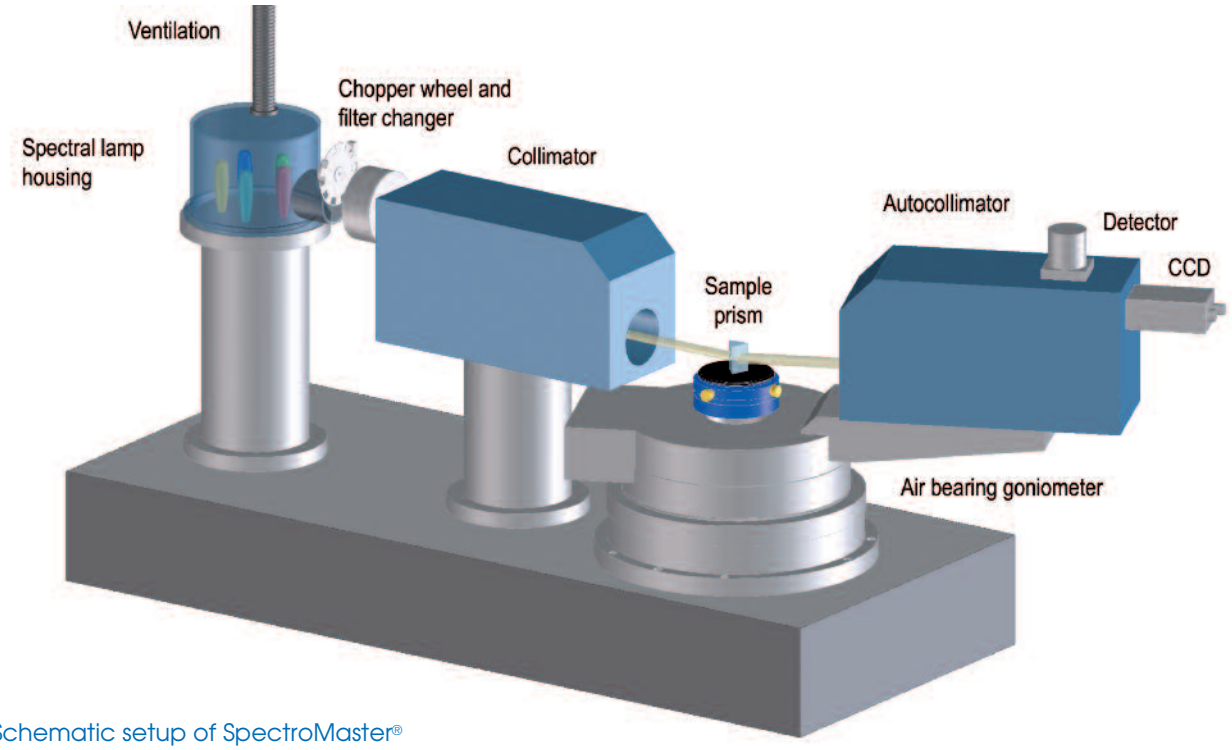
The air temperature should be stable and measured to 0.1 °C with the sample temperature in equilibrium or accurately measured independently. Typically, the influence of air humidity is negligible, but we recommend a RH value below 70%.

Sample Quality

If highest measurement precision is required, this puts some demands on the manufacturing quality of the prism samples. Generally a surface flatness of at least λ/10 or better is required, and the sample homogeneity should be better than the required index accuracy.

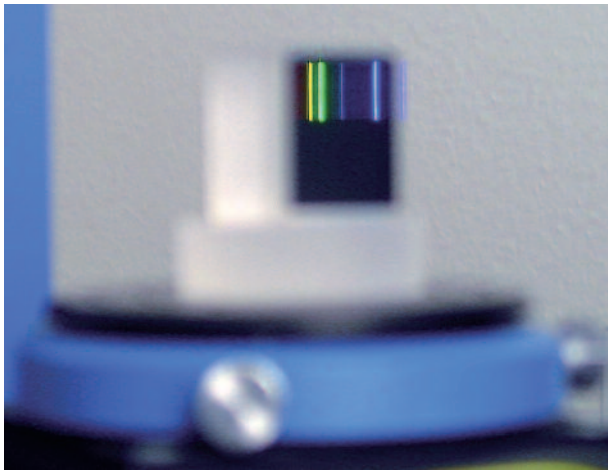
Principle of Operation

The principle measurement setup is shown above. A fixed collimator is projecting the image of a slit target through the sample prism. An autocollimator mounted to the rotary air bearing goniometer is picking up the slit image and measuring the deviation angle of the refracted light passing through the prism. The illumination of the variable target slit is done by exchange-



Schematic setup of SpectroMaster®

able spectral lamps, so that the measurements are done at precisely known wavelengths of selected spectral lines. For a better identification of certain spectral lines, narrow band interference filters can be moved into the beam path.
The autocollimator is also used for measuring the apex angle of the prism in reflection. It is supplied with a high-brightness LED illumination.
The sample is positioned on a fixed support centrally above the goniometer. With a rotary table, the incidence angle of the collimator beam with respect to the sample can be controlled. An optional linear stage can be used to move the prism to the optimum pivoting points for the apex angle measurement and the deviation angle measurement. The deviation angle measurements are done differentially on both sides of the collimator axis so that zero offset errors are suppressed.

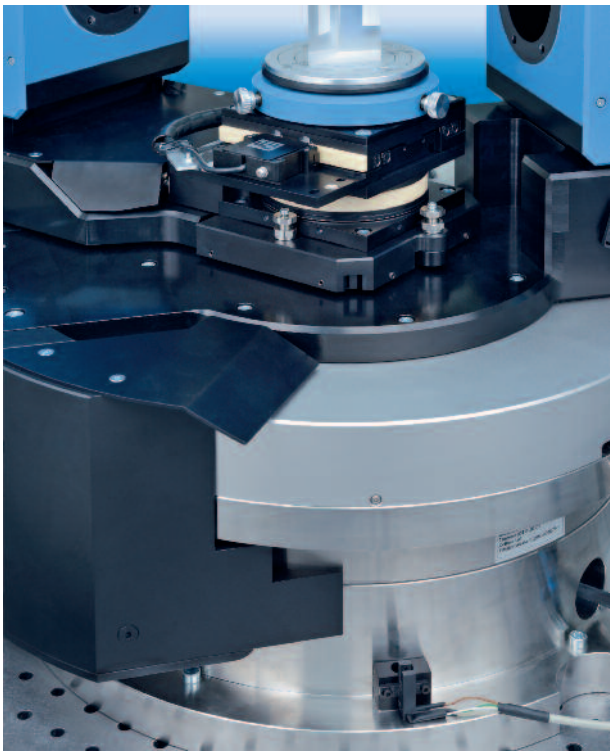


Spectral lines after refraction at the sample prism

The SpectroMaster® HR Universal models are completely designed with reflective optics, e.g. off-axis parabolic mirrors as focusing elements in the collimator and autocollimator. Special UV-enhanced coatings guarantee high reflectivity over the full spectral range. The extended spectral range also requires the use of additional photo detectors besides the CCD. For the infrared a cooled PbS-detector and for the UV a photomultiplier is used. For a better signal-to-noise ratio, the input beam is chopped by a frequency stabilized chopper wheel and a lock-in amplifier is used to process the detector signal.

Instrument Description

Rotary Air Bearing Goniometer



Air bearing table with ultra-accurate piezoelectric drive

The ultra-precision, high stiffness air bearing table is the key element of the SpectroMaster®, as it determines the angular resolution and measurement accuracy of the minimum deviation angle and apex angle, and thus the overall accuracy of the refractive index measurement. The axial and radial run-out errors of this bearing are smaller than 0.05 µm. It is supplied with an air control unit including pressure gauge and adjustment, particle filter and air dryer. An oil-free factory air supply net or a dedicated compressor is needed at the input of the air control unit. Further specification of the air supply is available upon request.

The goniometer embodies an ultra-precision Heidenhain encoder and a software-enhanced accuracy of better ± 0.2 arcsec. Specially selected goniometers are used for the SpectroMaster® HR instrument.

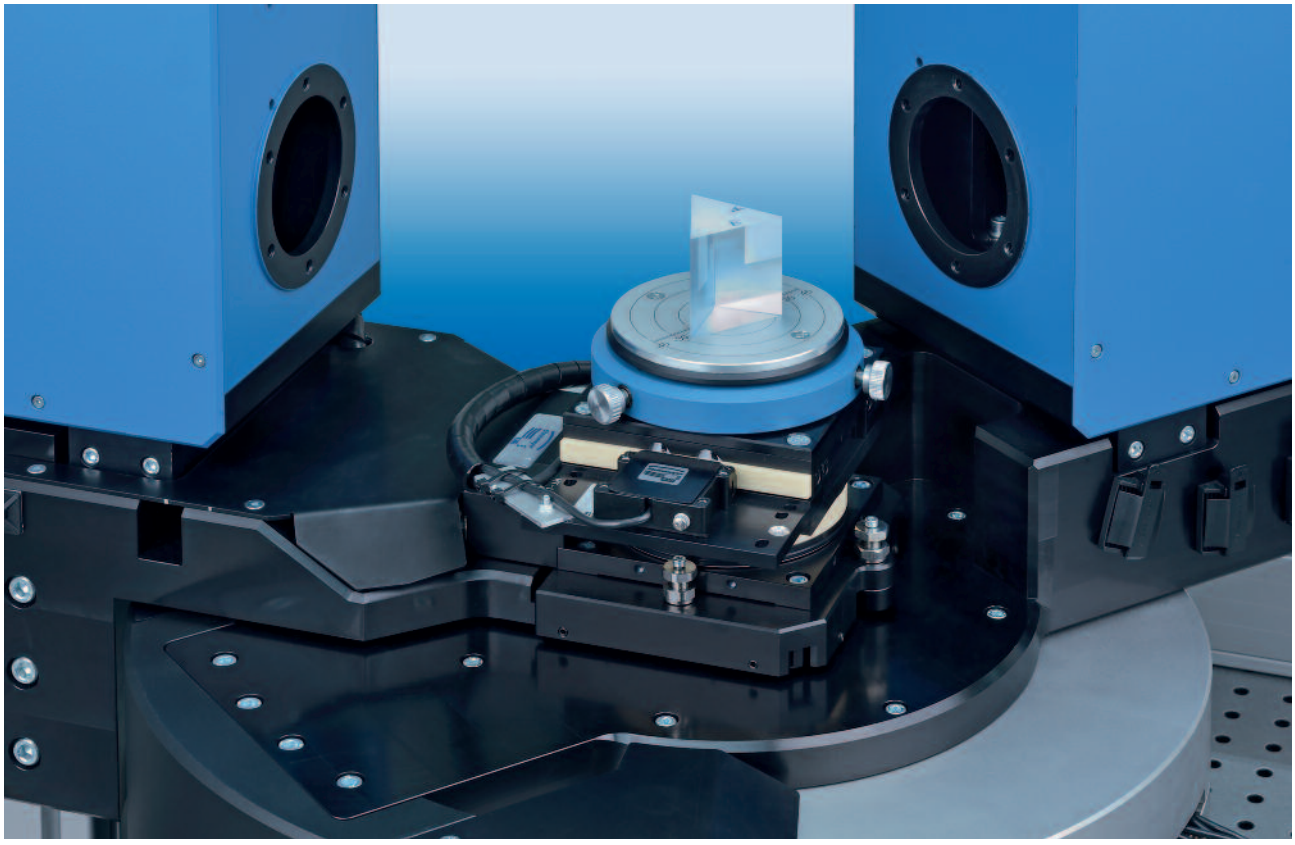
The motorized SpectroMaster® HR Universal is driven by a highly dynamic and ultra-precise backlash free piezo motor drive. The piezo motors generate no significant excess heat for optimum temperature stability at the place of the sample.

For the same reason, also the rotary and linear sample table stages are piezo driven. The piezo drive combines both, high measurement speeds and sub-arcsecond positioning accuracy.

The manual SpectroMaster® HR Compact employs a differential micrometer screw for highest sensitivity and accuracy during the manual adjustment of the telescope angle. Due to the sophisticated software assistance and alignment indicators, it has been proven that manual operators can reach the same high accuracy of the motorized version but at the cost of reduced measurement speed.

Collimator and Autocollimator

The mirror collimator and the mirror autocollimator include high performance off-axis parabolic mirrors with surface quality better λ/10. The focal length is 600 mm and the clear aperture 60 mm. Beam folding mirrors of the same surface and coating quality allow for a compact design. The coating is UV enhanced for best reflectivity over the full spectral range of 185..2325 nm. The autocollimator employs a geometric beam splitter design that ensures a wavelength independent focusing over the full measurement range of the CCD.



Mirror autocollimator and collimator unit

Detectors

The most convenient and fastest measurements are done with the CCD camera in the spectral range between 400..1050 nm. Optionally, a special UV-enhanced CCD camera is available which extends the usable UV range down to 250 nm. The CCD camera is also used for measuring the apex angle in autocollimation mode.

A photomultiplier tube allows measurements in the spectral range between 130 and 320 nm. Wavelengths below 193 nm are considered as Vacuum-UV and cannot be measured at standard laboratory conditions; however, experiments in nitrogen atmosphere have shown the possibility of Vacuum-UV measurements.

Vacuum-UV photomultiplier-tube (PMT) detector mounted on SpectroMaster® HR

For the infrared range 1000..2500 nm a two-stage thermoelectrically cooled PbS-Detector with dedicated low-noise amplifier is employed.

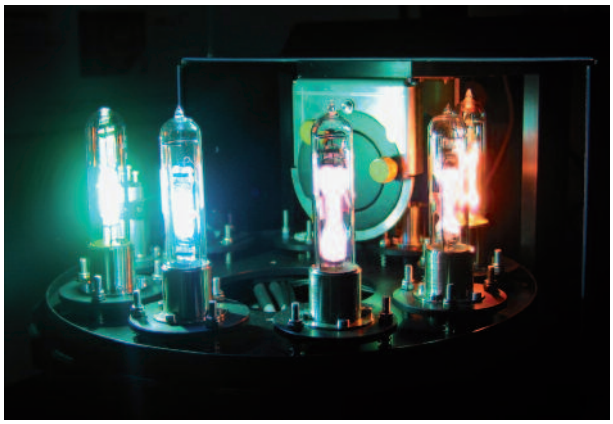
Thermoelectrically cooled PbS Infrared detector mounted on SpectroMaster® HR

A quick-change mount at the variable detector slit allows for the quick and easy exchange between both detectors and the mount of additional custom specific detectors.
The signal detection and amplification is performed by a laboratory grade lock-in amplifier for best signal-to-noise ratio and detection of even weakest spectral lines.

Illumination

Accurate refractive index measurements require the exact knowledge of the measurement wavelength. This is achieved by using low-pressure discharge spectral lamps. Spectral lamps generate a spectrum of discrete spectral lines with precisely known and stable wavelengths. The SpectroMaster® HR comes with a lamp house for up to 9 different spectral lamps on a rotating turret. It allows the quick change of the spectral lamp and the set of spectral lines to be measured. For optimum illumination of the target slit, the lamp house is equipped with a back reflecting mirror and quartz condensor optics. The standard set of 5 spectral lamps is given in the following table. Additional lamps are available on request.

A manual or (optionally) motorized filter changer wheel can be equipped with up to 18 narrow bandwidth interference filters for the easy selection and identification of the measurement spectral line. A set of standard filters is delivered with the instrument. Additional custom specific filters can be ordered separately.



Air bearing table with manual rotation and adjusting unit

Accessories

The instrument is delivered with a set of alignment tools for regular alignment checks of the instrument setup. A set of different spectral lamps and interference filters are provided on customer's order. TRIOPTICS can also provide one or more certified reference prisms for the traceable calibration of the instrument.

Standard set of spectral lamps

Hg	Mercury
Cd	Cadmium
Cs	Cesium
He	Helium
Na	Natrium

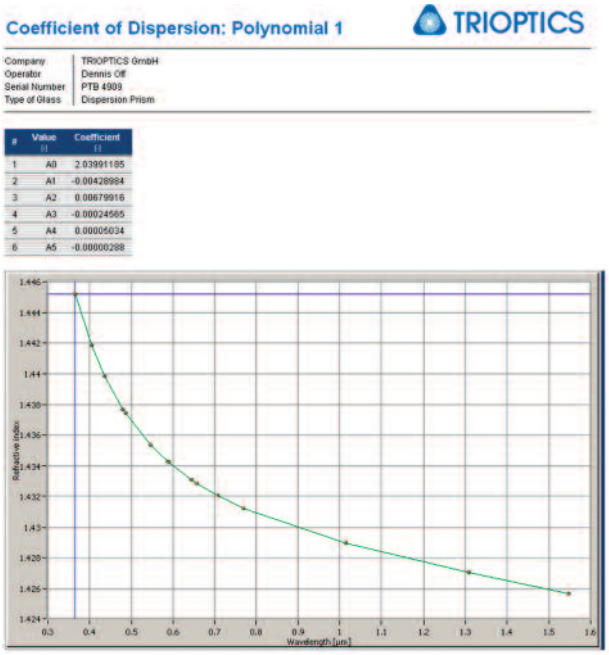
Filter wheel with interference filters

SpectroMaster® accessories: Alignment tools, detectors and reference prism

Measurement Results

The above graph shows typical measurement results and the fitted dispersion curve for a K5 glass prism over the full glass transmission range that can be measured. A fit module for the Sellmeier coefficients is included in the software, so that refractive index values can be estimated from measured ones at different wavelengths. The below plot shows the comparison of SpectroMaster® results and measurement data from an independent institute in the wavelength range 360..1100 nm. The low temperature coefficient of this S-BAL2 glass allows highly accurate measurements even in standard laboratory environment which is reflected by the residuals < +/- 2×10^{-6} compared to the reference values over the full measurement range.

Traceability of the SpectroMaster® measurement results is guaranteed by the careful final inspection using several PTB certified reference prisms available at TRIOPTICS.



Measurement results for an S-BAL2 sample prism

Comparison Measurement

TRIOPTICS

PTB Reference Sample:	No. 4737
PTB Certificate:	No. 1060 PTB 07 as of Dec. 13, 2007
Measurement Date:	15.03.2008, 11:33-12:44
Operator:	S. Krey
Material:	Quarz
Temperature:	21.1 °C
Air Pressure:	999.2 hPa

(Results corrected for normal conditions 20.1°C and 1013.25 hPa by Edlén formula)

Spectral Line		Refractive Index			Difference
Symbol	Wavelength	PTB 4737	SpectroMaster	SpectroMaster Std. Dev. 1σ	SpectroMaster-PTB
h	404.66	1.469629	1.4696295	4.E-07	5E-07
g	435.84	1.466705	1.4667048	3.E-07	-2E-07
F'	479.99	1.463513	1.4635138	4.E-07	8E-07
	508.58	1.461874	1.4618737	3.E-07	-3E-07
e	546.07	1.460089	1.4600884	3.E-07	-6E-07
C'	643.85	1.456714	1.4567141	4.E-07	1E-07

PTB Uncertainty (k=2) 2×10^{-6}

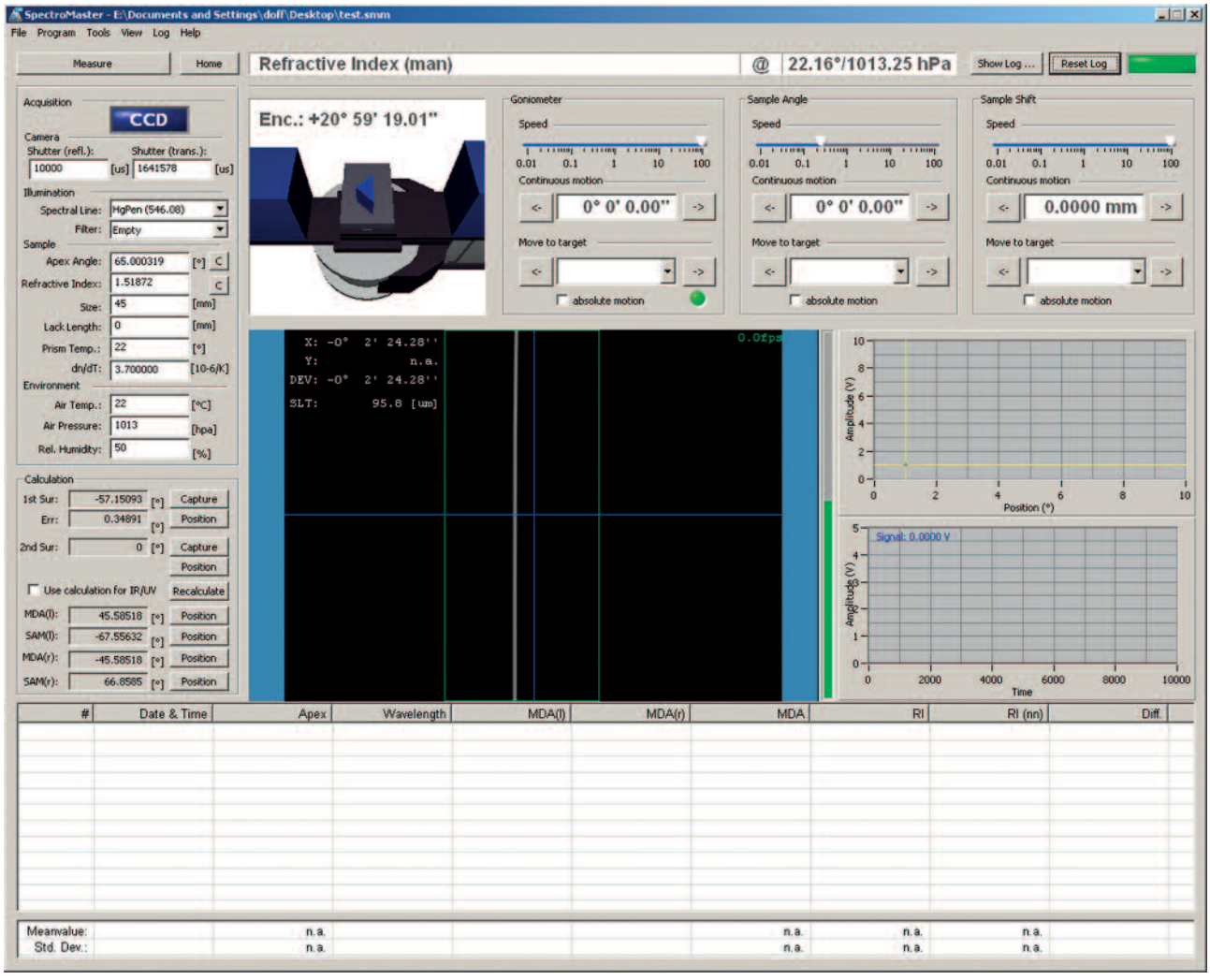
Measurement report for comparison of SpectroMaster® measurement results with PTB certified values

Each SpectroMaster® is delivered with comprehensive certificates showing its traceable measurement results within the specification.

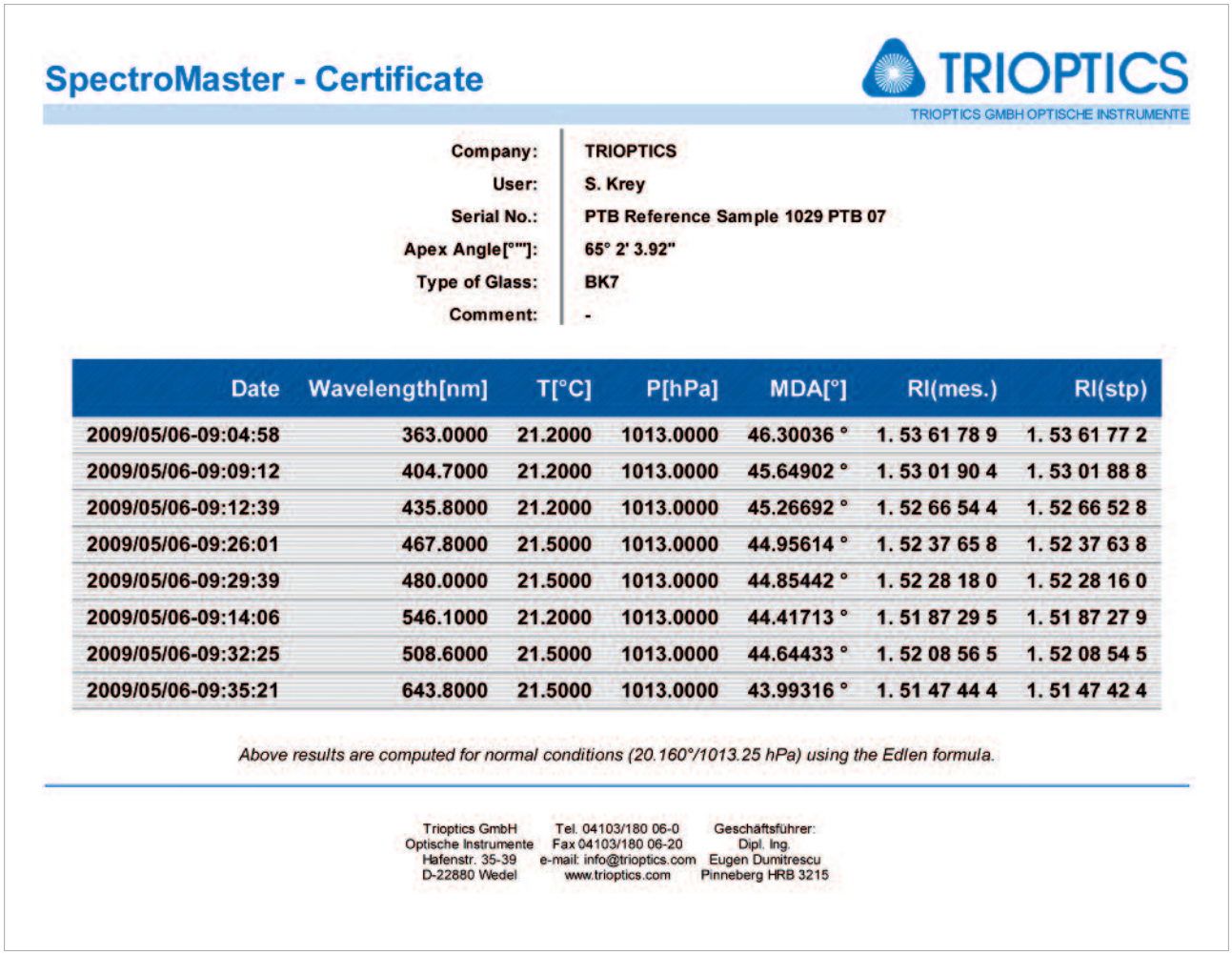
This certification is repeated during installation at customer's site. On request, the instrument can be delivered with a PTB certified master sample for regular checks by the customer. The below measurement report demonstrates exemplarily the excellent instrument accuracy with SpectroMaster® reproducing the PTB results within $<1\times10^{-6}$. Unfortunately, all national laboratories certify only in a limited visual range.

Software

The complete functionality of the SpectroMaster® instrument is controlled by an integrated Windows XP based software. It employs CCD-camera and photo detector readout, including the full configuration of attached amplifiers and controllers. With the motorized SpectroMaster® model, measurements can be performed fully automated over the complete spectral range of the chosen detector and spectral lamp. When for a certain glass type the approximate refractive index is known the software searches and measures automatically each programmed spectral



Main Instrument Control Dialog



SpectroMaster - Certificate

TRIOPTICS
TRIOPTICS GMBH OPTISCHE INSTRUMENTE

Company:	TRIOPTICS
User:	S. Krey
Serial No.:	PTB Reference Sample 1029 PTB 07
Apex Angle[°"']:	65° 2' 3.92"
Type of Glass:	BK7
Comment:	-

Date	Wavelength[nm]	T[°C]	P[hPa]	MDA[°]	RI(mes.)	RI(stp)
2009/05/06-09:04:58	363.0000	21.2000	1013.0000	46.30036 °	1. 53 61 78 9	1. 53 61 77 2
2009/05/06-09:09:12	404.7000	21.2000	1013.0000	45.64902 °	1. 53 01 90 4	1. 53 01 88 8
2009/05/06-09:12:39	435.8000	21.2000	1013.0000	45.26692 °	1. 52 66 54 4	1. 52 66 52 8
2009/05/06-09:26:01	467.8000	21.5000	1013.0000	44.95614 °	1. 52 37 65 8	1. 52 37 63 8
2009/05/06-09:29:39	480.0000	21.5000	1013.0000	44.85442 °	1. 52 28 18 0	1. 52 28 16 0
2009/05/06-09:14:06	546.1000	21.2000	1013.0000	44.41713 °	1. 51 87 29 5	1. 51 87 27 9
2009/05/06-09:32:25	508.6000	21.5000	1013.0000	44.64433 °	1. 52 08 56 5	1. 52 08 54 5
2009/05/06-09:35:21	643.8000	21.5000	1013.0000	43.99316 °	1. 51 47 44 4	1. 51 47 42 4

Above results are computed for normal conditions (20.160°/1013.25 hPa) using the Edlen formula.

Trioptics GmbH
Optische Instrumente
Hafenstr. 35-39
D-22880 Wedel

Tel. 04103/180 06-0
Fax 04103/180 06-20
e-mail: info@trioptics.com
www.trioptics.com

Geschäftsführer:
Dipl. Ing.
Eugen Dumitrescu
Pinneberg HRB 3215

SpectroMaster® Measurement Certificate

line and gives a report on the actual index values with highest accuracy. Additionally, sophisticated tools allow the quick and easy characterization of unknown glass types, so that accurate refractive index data can be obtained in a few minutes. Of course, the software performs the correction of the measurement data to take into account the ambient air refractive index depending on temperature and pressure.

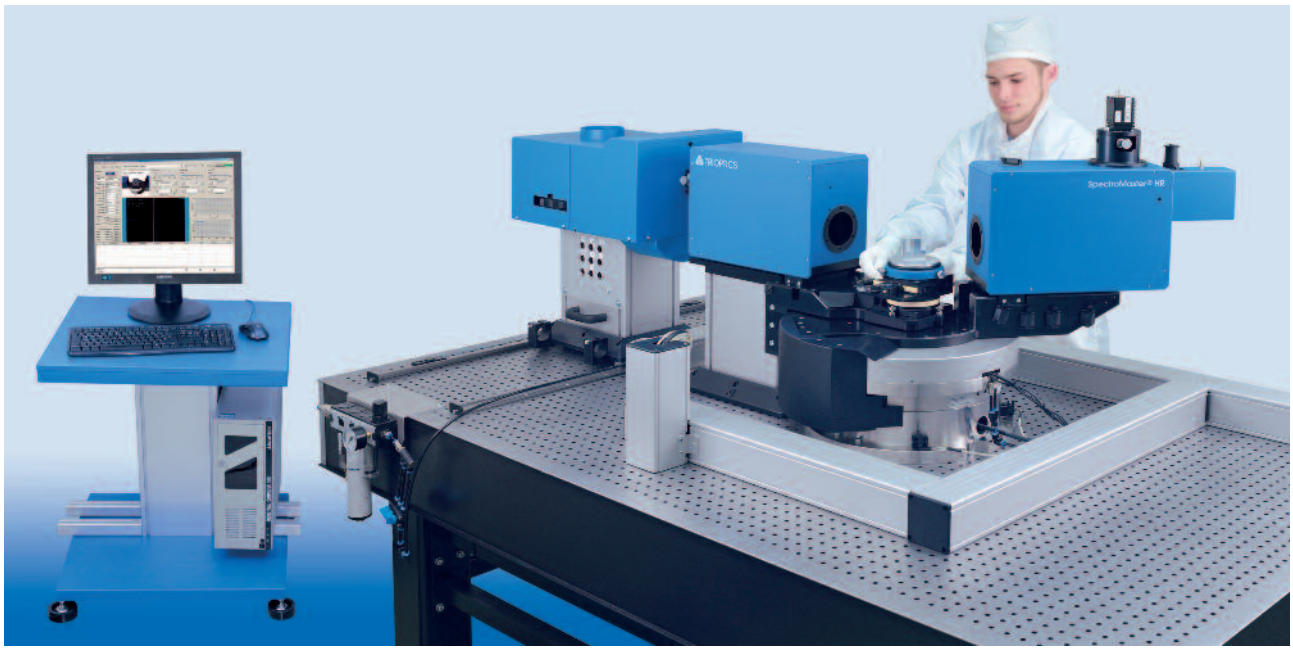
In CCD camera measurements the software relies on the approved image analysis algorithms of TRIOPTICS PrismMaster® and OptiAngle® instruments for the accurate detection of spectral line positions. In scanning photo detector measurements, the spectral line profiles are automatically scanned and the line center position is determined with highest precision. The complete motorization gives the maximum independence from operator skills and makes repeatability in the range of 10^{-7} possible. However, it was proven that the manual models could reach the same high system accuracy due to precise alignment indicators assisting the operator in gaining maximum accuracy.

Of course, the software generates a complete and detailed measurement certificate. For further analysis, a MS Excel compatible output format is available, too.

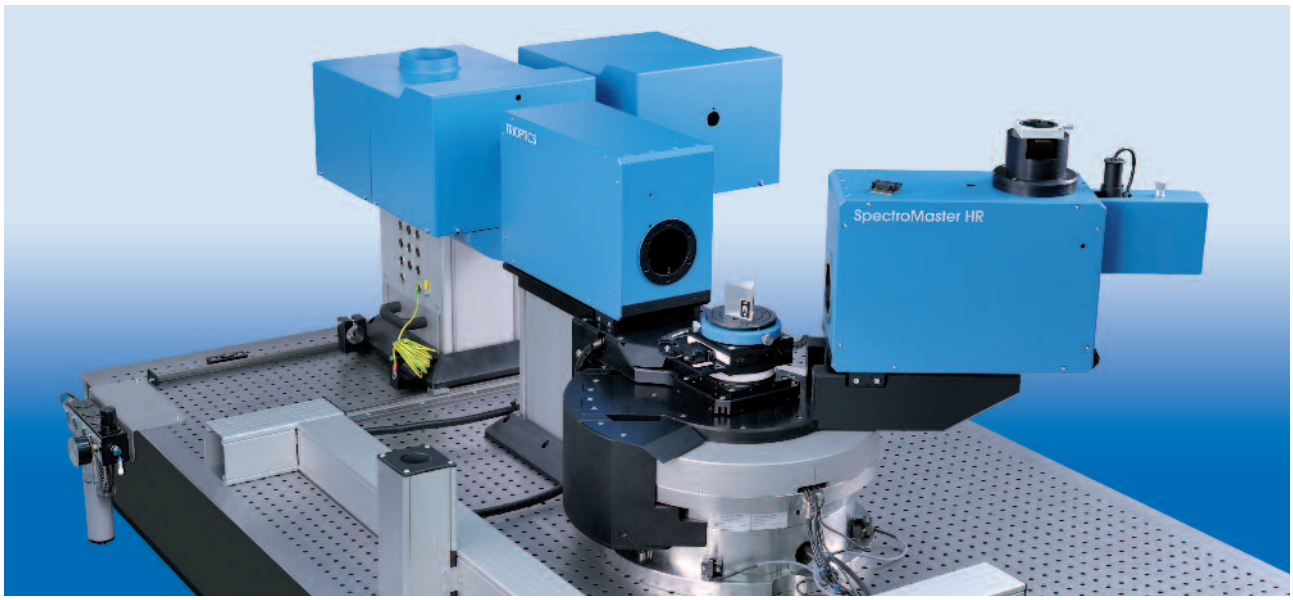
SpectroMaster® Product Range

SpectroMaster® HR Universal

The SpectroMaster® HR Universal is the most accurate refractive index measurement system currently on the market. This precision is the result of ultra-high precision components like the air bearing rotary table or the high-class mirror optics and the high-quality manufacturing with careful inspection of all relevant parameters. The instrument is available in both motorized and manual version, where the motorized goniometer is equipped with backlash free piezo motors of negligible power dissipation for optimum thermal stability.



Complete setup of SpectroMaster® UV-VIS-IR HR with motorized goniometer



SpectroMaster®

SpectroMaster® HR Compact

The SpectroMaster® HR Compact is using refractive optics and is thus limited to the visible spectral range between 436... 644 nm.

The high accuracy of this instrument is achieved by special focusing optics, so that the telescope and the collimator can be focused to best collimation at the specific measurement wavelength.

SpectroMaster® HR Compact

SpectroMaster® HR Compact in use®

Summary of Specification

	SpectroMaster® HR Universal	SpectroMaster® HR Compact
Maximum Wavelength Range	195-2325	365-1014
Standard	UV, VIS (visible), SWIR (short wave IR)	VIS (visible)
Optional	MWIR (mid wave IR), LWIR (long wave IR)	NUV (near UV), NIR (near IR)
Apex Angle Measurement Accuracy	0.2 arcsec	0.5 arcsec
Refractive Index Measurement Accuracy	UV 195nm - 365nm $3x10^{-6}$ VIS 365nm – 1014nm $2x10^{-6}$ SWIR 1014nm – 2325nm $5x10^{-6}$ (Sample size at least 10mm) (Temperature controlled to 0.1°)	VIS: $5x10^{-6}$ (Temperature controlled to 0.1°)
Collimator	- off-axis parabolic mirror collimator - adjustable target slit	Focusing refractive collimator
Autocollimator	- off-axis parabolic mirror autocollimator - geometric beam splitter	Focusing refractive autocollimator
Spectral lamp housing	- mounting space for 9 spectral lamp on a rotary stage for quick manual selection - filter changer for 17 interference filters	spectral lamp housing for a single (HgCd lamp)
Detector	- CCD - PbS for SWIR - PMT for UV	CCD
Order Number	5-107-11	5-108-01

Goniometer	
Ultra-high precision rotary air bearing, axial and radial run-out <0.05 µm, high precision angular encoder Measuring range +/- 100°, Air supply unit	
SpectroMaster® HR Universal	Angle measurement accuracy 0.2 arcsec
SpectroMaster® HR Compact	Angle measurement accuracy 0.5 arcsec
Motorized	Highly dynamic backlash free piezo motor drive with negligible thermal dissipation
Manual	Differential fine-pitch micrometer screw with software assisted adjustment help

SUMMARY OF SPECIFICATION

TRIOPTICS GMBH · OPTICAL TEST EQUIPMENT

Collimator	
SpectroMaster® HR Universal	• Off-axis parabolic mirror collimator • Mirror surface quality better λ/10 • UV-enhanced coating • Clear aperture 60 mm • Focal length 600 mm • Adjustable target slit
SpectroMaster® HR Compact	• Focusing refractive collimator • Clear aperture 50 mm • Focal length 300 mm

Autocollimator	
SpectroMaster® HR Universal	• Off-axis parabolic mirror autocollimator • Mirror surface quality better λ/10 • UV-enhanced coating • Clear aperture 60 mm • Focal length 600 mm • Geometric beam splitter • LED illumination • High-resolution CCD camera • (optionally) UV-enhanced CCD • UV/IR detector mount with adjustable detector slit
SpectroMaster® HR Compact	• Focusing refractive autocollimator • Clear aperture 50 mm • Focal length 300 mm • LED illumination • High-resolution CCD camera

Detectors (SpectroMaster® HR Universal only)
• 2-stage thermoelectrically cooled PbS detector incl. thermal controller, preamplifier and bias voltage supply Spectral range 1000...2325 nm • Photomultiplier tube incl. voltage supply and low-noise preamplifier Spectral range 185...320 nm • UV enhanced CCD camera Spectral range 250...1050 nm • Signal detection by laboratory grade lock-in amplifier

Spectral lamp housing	
SpectroMaster® HR Universal	• Mounting space for 9 spectral lamps on a rotary stage for quick manual selection • Integrated rear reflector mirror • Removable fused silica condensor optics • Electronically stabilized chopper wheel • Motorized filter changer for 18 interference filters (manual filter changer on manual goniometer models) • Spectral lamp power supply
SpectroMaster® HR Compact	• Spectral lamp housing for a single (HgCd) • Spectral lamp power supply • fused silica condensor optics

Sample stage	
Sample table with 3-axis (120°) tilt adjustment screws	
SpectroMaster® HR Universal	• Piezo drive linear stage for sample position adjustment • Piezo drive rotary stage for sample rotation • Rotary encoder for measurement of sample rotation angle
SpectroMaster® HR Compact	• Precision manual linear stage for sample position adjustment • Precision manual rotary stage for sample rotation • Rotary encoder for measurement of sample rotation angle

Table of typical wavelengths for refractive index measurement

Number	Wavelength (nm)	Symbol	Spectral lamp type
1	194,2nm		Hg
2	253,7nm		Hg
3	296,7nm		Hg
4	312,6nm		Hg
5	334,1nm		Hg
6	365.0nm	i	Hg
7	404.6nm	h	Hg
8	435.8nm	g	Hg
9	479.9nm	F´	Cd
10	508.6nm		Cd
11	546.1nm	e	Hg
12	587.6nm	d	He
13	589.3nm	D	Na
14	643.8nm	C´	Cd
15	706.5nm	r	He
16	852.1nm	s	Cs
17	1013.9nm		Hg
18	1529,6nm		Hg
19	1970,1nm		Hg
20	2325,4nm		Hg

TRIOPTICS

TRIOPTICS GmbH · Optische Instrumente
Hafenstrasse 35-39 · 22880 Wedel / Germany
Phone: +49-4103-18006-0
Fax: +49-4103-18006-20
E-mail: info@trioptics.com · http://www.trioptics.com