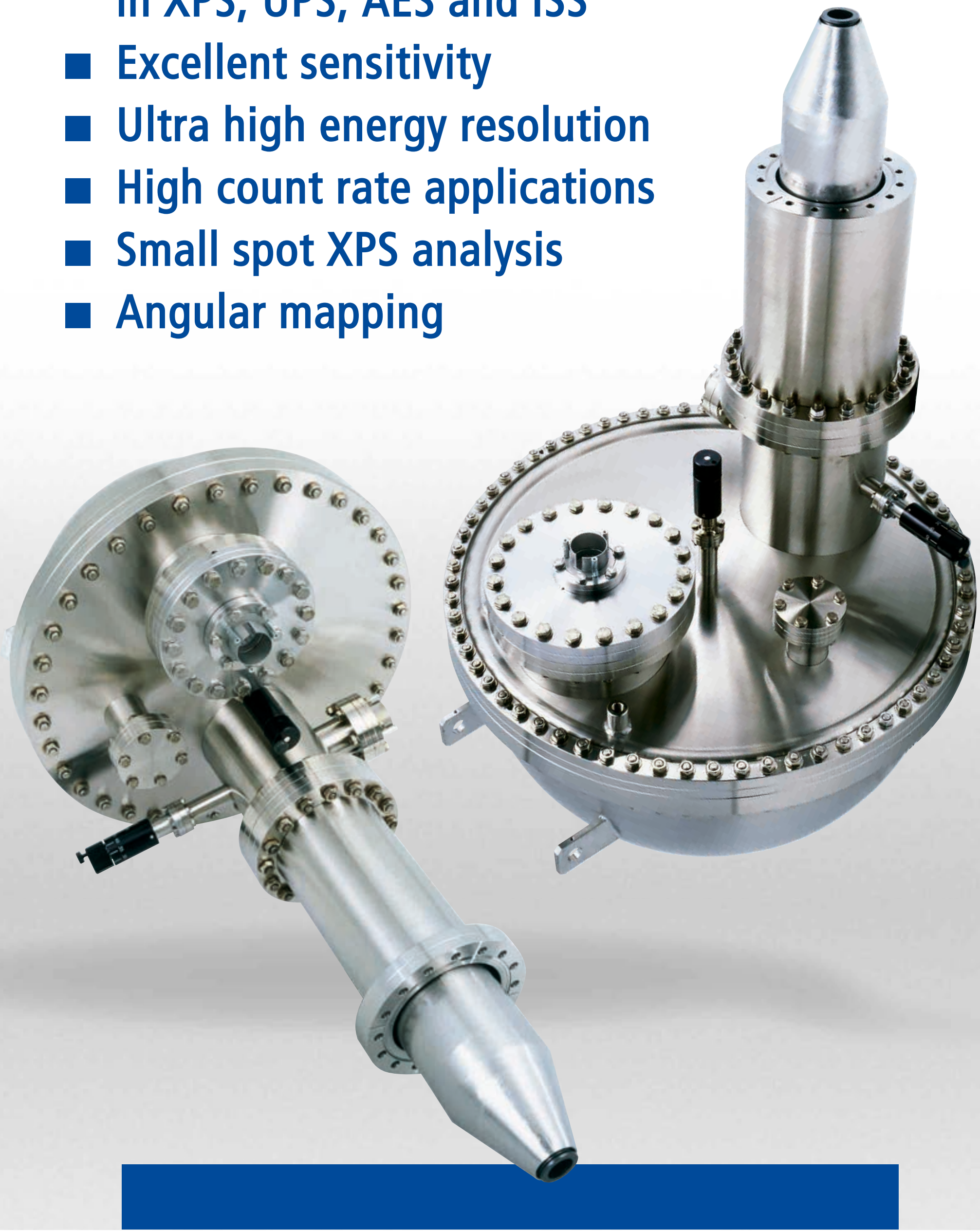
COMPONENTS FOR SURFACE ANALYSIS

State of the Art
Energy Analyzer Series

PHOIBOS 100/150

- Superior performance in XPS, UPS, AES and ISS
- Excellent sensitivity
- Ultra high energy resolution
- High count rate applications
- Small spot XPS analysis
- Angular mapping

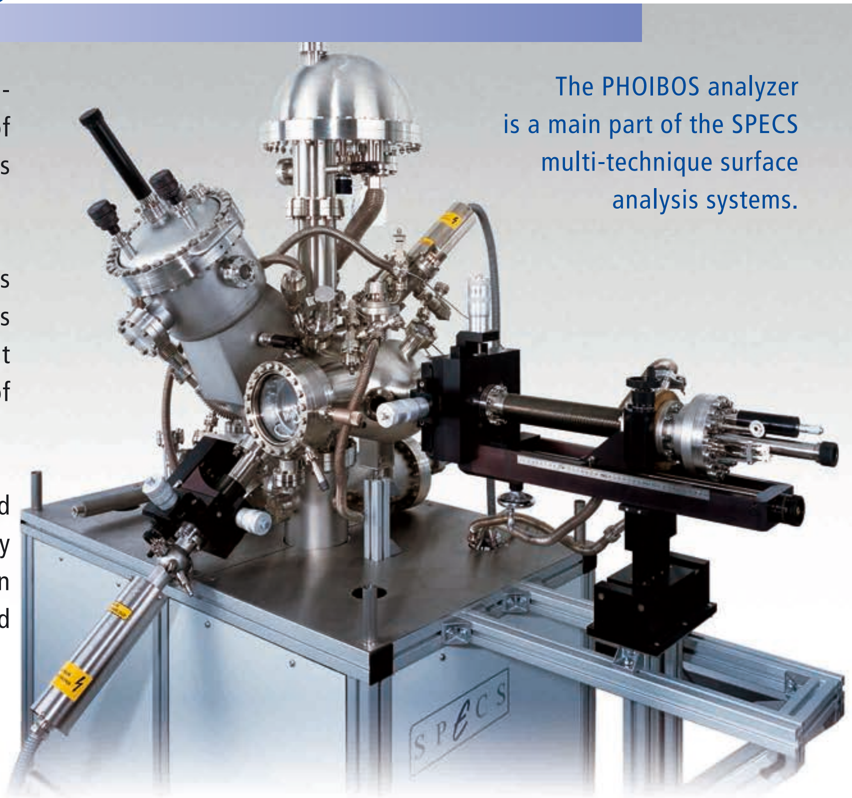


PHOIBOS 100/150

With the new generation of the well-tested and proven PHOIBOS series of hemispherical energy analyzers SPECS sets a new standard.

New approaches and technical solutions lead to an instrument that combines excellent performance with the highest reliability for the largest possible variety of experimental conditions.

Most advanced and sophisticated computer simulations were used to fully characterize and optimize the electron optical properties of the analyzer and transfer lens.



The PHOIBOS analyzer is a main part of the SPECS multi-technique surface analysis systems.

PHOIBOS

The Greek deity Apollo was often called PHOIBOS Apollo, an epithet that means "bright".

Analyzer

- True 180° hemispherical energy analyzer with 100 or 150 mm mean radius
- Exclusive use of non-magnetic materials inside μ-metal shielding
- Sophisticated Slit Orbit mechanism for external setting of 8 entrance and 3 exit slits

The PHOIBOS analyzer is available with 100 and 150 mm mean radius (see PHOIBOS 225 catalogue for information on the PHOIBOS analyzer with 225 mm mean radius).
Due to the modular concept of the construction, the analyzer can be easily adapted to meet special requirements.

Highly effective fringe field corrections in the entrance and exit areas result in excellent energy resolution at very low kinetic energies as demonstrated in various benchmark tests (see Xe $5p_{3/2}$ gas phase UPS spectrum).

With the new sophisticated Slit Orbit the user can independently select one of 8 pairs of entrance slits and one of 3 exit slits via one rotary drive from outside the vacuum. Entrance and exit slits can be operated independently.
In each pair of entrance slits one slit defines the energy resolution while the other slit serves to match the angular spread for the analyzer. This arrangement allows optimum transmission for all chosen slit sizes and resolution settings.

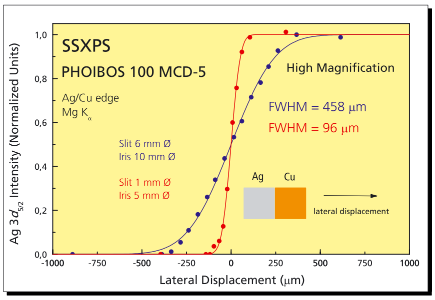
For ultimate performance the analyzer and the lens system are constructed entirely from non-magnetic materials inside the μ-metal shielding. A view port is provided for through the lens (optical) alignment.

Transfer Lens

- High étendue for XPS and UPS
- High point transmission for synchrotron, AES and ISS applications
- Multimode transfer lens for angular and spatially resolved studies
- Iris diffraction plane aperture
- Small spot analysis down to 100 µm resolution

The multi-element, two-stage transfer lens was designed to yield ultimate transmission and well-defined optical properties. It may be operated in several different modes for angular and spatially resolved studies to adapt the analyzer to different tasks. All lens modes can be set electronically.
The standard working distance of 40 mm and the 44° conical shape of the front part of the lens provide optimum access to the sample for all types of excitation sources.

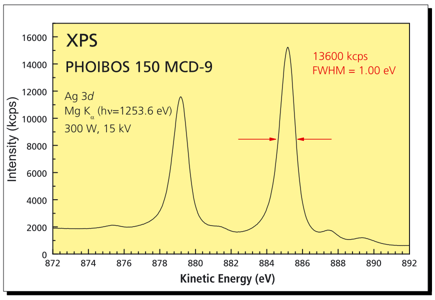
For small spot analysis, a lateral resolution down to 100 µm is available using the High Magnification Mode and the novel Iris aperture. In the Magnification Modes, angular resolution is accomplished with an Iris aperture in the diffraction plane of the lens system. Using this Iris the angular acceptance can be continuously adjusted between ±1° and ±9° while keeping the acceptance area on the sample constant.
The Area Modes were optimized to allow very high transmissions for different spot sizes of the source.



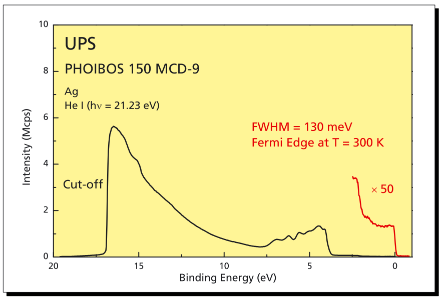
Small Spot XPS at a Ag/Cu edge with a broad illuminating source using the Iris aperture. The typical broadening of the acceptance area due to lens aberrations is eliminated.

In the Angular Dispersion Modes, electrons leaving the sample within a given angular range are focussed on the same location on the analyzer entrance independent of their position on the sample. The angular modes allow the user to optimize the angular resolution down to ±0.05° with the Slit Orbit.

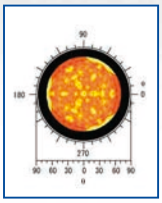
With a 2-D detection system, high angular resolution can be achieved in the nondispersion direction of the analyzer without restricting the acceptance angle (Angular Mapping). These modes are the ideal choice for angular dependent studies.



The Ag 3*d* peak obtained with the PHOIBOS 150 MCD-9 demonstrates the high étendue of the analyzer and the transfer lens.



With the high brightness SPECS ultraviolet excitation sources the PHOIBOS analyzer series guarantees superior performance in ultraviolet photoelectron spectroscopy.



Experimental XPD photoelectron hologram of bulk 2*s* emission from Si(111) excited by Mg Kα using a PHOIBOS 150 MCD-9 analyzer. The angular resolution was set with the Iris to 1° (data with courtesy of T. Matsushita, A. Agui and A. Yoshigoe, Spring-8, Japan).

Étendue

The product of area and solid angle of the electrons accepted by the spectrometer.

This specification is required to determine XPS sensitivity.

Point Transmission

For a point source, defined as the solid angle over which charged particles are accepted by the spectrometer and transmitted to the dispersing element.

This specification is required to determine point source sensitivity.

Broadening

The FWHM for a Gaussian broadening at an edge is equivalent to a 12 to 88% intensity change across the step edge.

A 20 to 80% rule defines a value which is only 0.71 of the Gaussian broadening.

Acceptance Area

A focused electron beam rastered over the sample area could be used to determine the FWHM of the acceptance area without restricting the acceptance angle with an aperture.

With a broad illuminating X-ray source also small intensities from outside the analysis area can contribute considerably to the signal. The Iris aperture eliminates these contributions.

Mode	Acceptance area	Acceptance angle	Typical Applications
Spatially resolved	Entrance slit size divided by M independent of analyzer settings. Slit sizes 7x20, 3x20, 1x20, 0.5x20, 0.2x20, ∅ 7, 3 and 1 mm	Continuously adjustable down to ±1° using Iris aperture	Small area XPS, UPS standard ARXPS and ARUPS
High Magnification	Magnification M = 10	Up to ±9°	
Medium Magnification	Magnification M = 3	Up to ±6°	
Low Magnification	Magnification M = 1	Up to ±3°	
Transmission optimized	Optimized for different spot sizes of the source Typical spot size		Large Area XPS Monochromated XPS AES, ISS and synchrotron studies
Large Area	∅ 5 mm	Up to ±5°	
Medium Area	∅ 2 mm	Up to ±7°	
Small Area	∅ 0.1 mm	Up to ±9°	
Angular resolved	Slightly decreasing with increasing retarding ratio and independent of slit sizes	Entrance slit size divided by D independent of analyzer settings Slit sizes 7x20, 3x20, 1x20, 0.5x20, 0.2x20, ∅ 7, 3 and 1 mm	Low kinetic energy applications. High angular resolved ARXPS / ARUPS with a 2D detection system (Angular Mapping)
High Angular Dispersion		D = 3.2 mm / ° (±3° acceptance)	
Medium Angular Dispersion		D = 2.2 mm / ° (±4° acceptance)	
Low Angular Dispersion		D = 1.2 mm / ° (±7° acceptance)	
Wide Angle Mode		D = 0.5 mm / ° (±13° acceptance)	

The table shows the lens modes of operation. The multi-element transfer lens of the PHOIBOS analyzer may be operated in several different modes: spatial resolution, optimzed transmission or angular resolution (see table). Additional acceleration modes for low kinetic energy applications are available (HighMagnification2 and SmallArea2).

Power Supply

- One power supply for all analyzer operation modes
- Modular design / architecture
- Including detector high voltage modules
- Fully digitized power supply
- 24 bit high-precision voltage modules
- Truly bipolar
- Very short settle times
- Super low noise modes

With the HSA 3500 plus SPECS presents a new versatile high voltage power supply for electrostatic field applications. The modular design of the unit allows independent setting of all voltages - no voltage dividers are used.

Each module is fully galvanically floating, highly stable and linear. The voltages are controlled by high-precision 24-bit digital-to-analog converters with an overall maximum settle time of 3 ms.

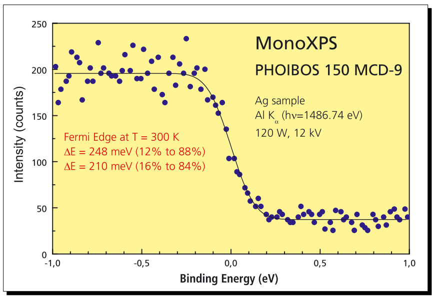
Each module is equipped with a microcontroller allowing independent setting of all voltages. Analog-to-digital converters for output voltages and output currents facilitate diagnosis and error localization.
The complete electronics package is contained in a single 19” standard rack housing with removable cables.

The power supply can be operated in FAT (Fixed Analyzer Transmission) or FRR mode (Fixed Retarding Ratio).
Both pass energy and retarding ratio can be continuously adjusted to fine-tune resolution and intensity.

With an energy span of ±3500 eV the power supply of the PHOIBOS analyzer provides a wider energy range than most other instruments and gives access also to the high kinetic energy lines.

For ultra high energy resolution applications the unit can be operated in a 400 V or a 10 V bipolar range and a 100 V unipolar range with extremely low ripple. Step widths down to 20 μeV are possible. These ranges guarantee extraordinary stability and low-noise, allowing ultra high resolution measurements.

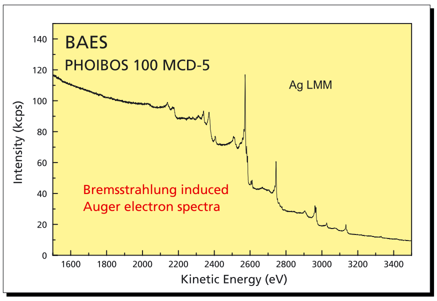
The power supply provides the fast and reliable CAN Bus interface and an internal microprocessor for fast and reliable processing and remote control. The temperature stability of the analyzer voltage modules are better than 1.5 ppm of the voltage span per °C.



The spectrum shows the Fermi edge of Ag at 300 K measured with monochromated XPS. The width of the edge is 210 meV (84% to 16 %).

BAES

Bremsstrahlung induced Auger Electron Spectroscopy



The advantage of BAES is a considerably improved signal-to-noise ratio compared to AES, because the background signal from inelastically scattered primary electrons is eliminated. This makes it unnecessary to differentiate the spectra.

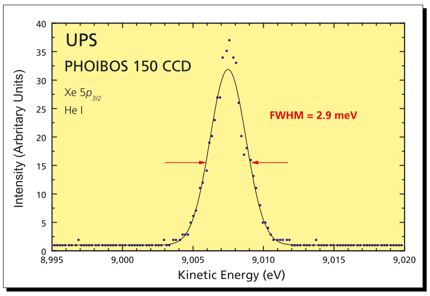
HSA 3500 PLUS MODES OF OPERATION

Range	Typical Application	Minimum Step Width	Ripple	Pass Energy
0 ...±3500 V	AES, ISS and XPS	7 meV	1 mV	0 ... 660 eV
0 ...±1500 V	XPS	3 meV	0.5 mV	0 ... 100 eV
0 ... ±400 V	UPS	800 μeV	250 μV	0 ... 200 eV
0 ... -100 V	UPS	125 μeV	250 μV	0 ... 50 eV
0 ... ±10 V	UPS	20 μeV	N/A	0 ... 5 eV

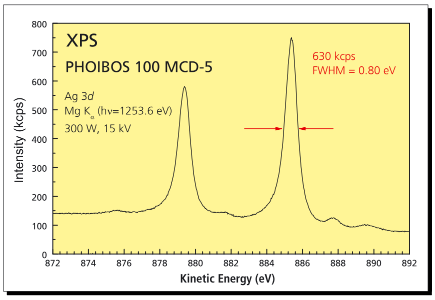
ULTRA HIGH ENERGY RESOLUTION

ANALYZER RESOLUTION

The data shows that the broadening due to the analyzer (<1 meV) and UV source (1 meV) can be neglected compared to the Doppler broadening of the Xe target gas.



The Xe 5$p_{3/2}$ gas phase spectrum demonstrates the high energy resolution capability of the PHOIBOS hemispherical energy analyzer.



The intensity of the Ag 3$d_{5/2}$ photoelectron peak with a FWHM of 0.80 eV illustrates the resulting high count rate for a measurement with high energy resolution excited with non-monochromatized MgK$_\alpha$.

Detection

- Ultra-fast, low-noise preamplifier and counter
- Single channel or multi channel detection with up to 9 channels
- MCD, CCD, Spin or Delay Line Detector can be retrofit on-site

PHOIBOS analyzers are equipped with a flange-mounted detector assembly.

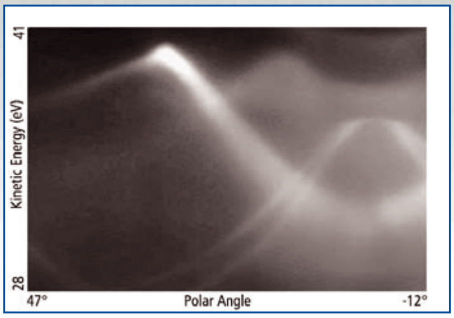
The standard detector assembly consists of either one, five or nine single channel electron multipliers (SCD, MCD-5 or MCD-9) arranged as a single block which provides both compactness and durability. Channel electron multipliers with an extended dynamic range for extremely high count rate applications are used as standard. Upgrades from single to multi channel detection can be performed on-site.

The design of the detection electronics takes into account the need for reliable counting results even in difficult environments and for extended dynamic ranges.

Other detector types, such as 2D-CCD, 1D-Delayline (70 or 100 channels), 3D-Delay-Line or Spin Detectors can easily be retrofit without modification to the PHOIBOS 100 or 150 analyzer.

The 2D CCD detector system simultaneously uses both the energy and angular resolution of the analyzer for band mapping, angular mapping, high resolution XPS/UPS (see p. 5 Xe 5$p_{3/2}$ spectrum), and image state spectroscopy with 2PPE.

The system features a 12-bit digital CCD camera with a dynamic range of 1000. The detector design is especially optimized for the detection of low kinetic energy electrons.



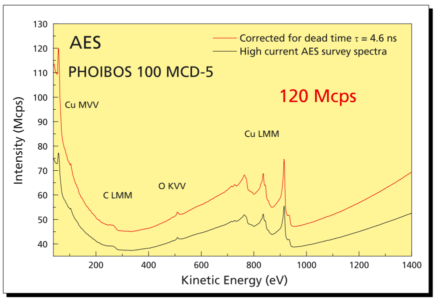
Band structure of crytalline graphite measured at room temperature. The analyzer entrance slit size used was 0.5 mm wide and the pass energy 80 eV. The angular mode used, Wide Angle Mode, allows one to simultaneously measure an angular range of ±13°. The acquisition time for each image was 50 s. Between each image the sample was rotated 15° around the polar axis (data with courtesy of T. Balasubramanian, MAX-Lab, Sweden and R. Uhrberg, Lingköping University, Sweden).

The 1-D delayline detector with 70 or 100 channels is a reasonable alternative for high resolution XPS and snap shot capabilities.

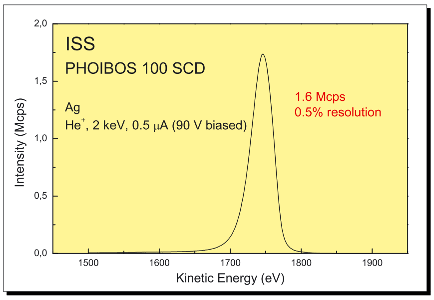
The 3-D (one time and two lateral dimensions) segmented delay-line detector system using the new hybrid design (segmented delay-line) combines high countrates (50 MHz) with extremly high temporal resolution (125 ps) in one device.

The SPECS Spin detector is based on the established Rice University micro-Mott design. It detects two Spin components in addition to six standard MCD channels.

High transmission for AES and ISS



The high current AES survey spectrum shows the high count rate capability of the PHOIBOS detection system with the extended dynamic range CEMs.



Ion scattering spectroscopy (ISS), performed with inverse polarity at the analyzer electrodes, is included in the standard package of analyzer and power supply.

Dead time

For a detection system with a dead time t the observed count rate N1 and the true count rate N is related by

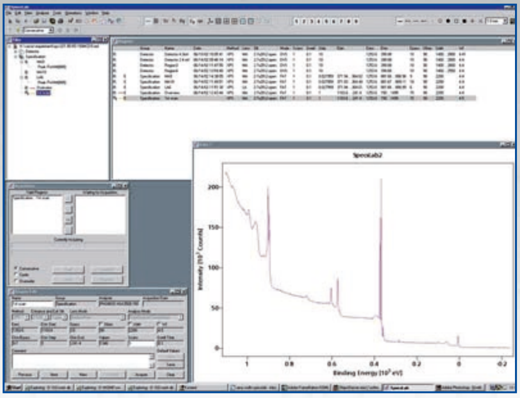
N1 = N / (N τ +1)

Data Acquisition & Processing

- Windows operating system
- Predefined measurement limited only by computer memory
- All analyzer operating modes supported
- XPS and AES database
- CasaXPS for data processing

The SPECS software package combines ease of operation with powerful data acquisition and analysis routines. The data acquisition and data processing software provides computer control of all analysis methods possible with the PHOIBOS analyzer.

Predefined sequence measurements are limited only by computer memory and disk space. For synchrotron applications, including ARUPS, CIS and CFS experiments, external components such as stepper motors or monochromators can be controlled directly or by CORBA (Common Object Request Brokerage Architecture) interfaces. These interfaces can be easily programmed in C++. User defined lens curves are possible for spectrometer operation.



SpecsLab data acquistion software

For MCD detectors, the user has online access to the separate channels. A semi-automatic dispersion calibration ensures optimal resolution and energy calibration for all analyzer settings. An MCD ratemeter is included.

Standard data processing tools include background subtraction (linear, Shirley and Tougaard background), satellite subtraction, smoothing, integration, differentiation, numerical operations, scaling, view options, shift, work function adjustment and much more. Peak fitting routines and quantification with easily configurable files for peak parameters (including database for XPS and AES) result in comprehensive surface analysis software for a wide range of applications.

Performance

COUNT RATES

All values specified in the table are in cps for the signal above the background.

	Resolution	SCD	MCD-5	MCD-9
XPS	Ag $3d_{5/2}$, Mg K_{α} , 15 kV, 300 W, distance sample-anode <15 mm			
	0.85 eV	300,000	1,700,000	3,000,000
	1.00 eV	900,000	4,600,000	9,000,000
	1.40 eV	2,000,000	12,000,000	26,000,000
UPS	Ag valence band, He I, (*) Fermi edge width (12 to 88%) at T=300 K			
	140 meV*	2,000,000	10,000,000	20,000,000
AES	Cu LMM, 20 nA sample current (+15 V bias), 5 keV			
	0.5 %	300,000	1,500,000	3,000,000
ISS	Ag , 0.5 μA sample current (+90 V bias), 2 keV, He^+			
	0.5 %	1,200,000	6,000,000	12,000,000

Technical Data

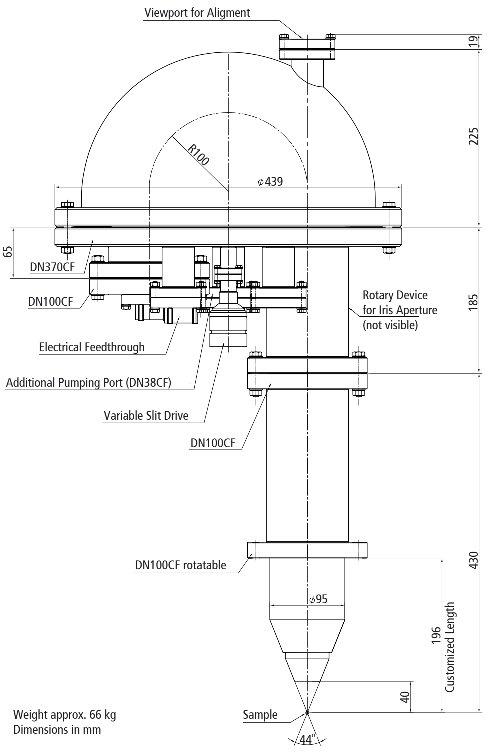
Detection electronics PCU 300

Channels	1, 5 or 9
Preamplifier	300 MHz
Input Impedance	50 Ω
Threshold Level	4 to 200 mV
Additional electronic dead time	6 ns to 160 ns
Counter	160 MHz, 24 bit per channel
Data transfer	fully digital via on-board CAN bus interface
Mounting	directly on detector flange single multi-pin feedthrough
Size	69 x 104 x 163 mm^3
Housing	RF-shielded aluminum case

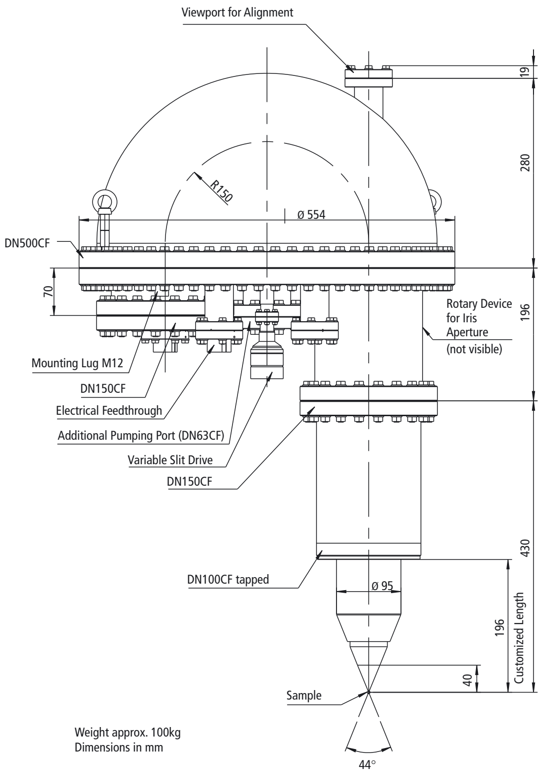
Power supply HSA 3500 plus

Interface	CAN bus
D/A converters	24 bit, high-precision and highly stable
Lens modes	12 modes spatially and angular resolved
Detector supply	0 to 3500 V
Size	19" (W) x 310 mm (H) x 511 mm (D)
Weight	19 kg

PHOIBOS 100



PHOIBOS 150



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