



EA 125 Energy Analyser

User's Guide

Version 2.1

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Preface

This document has been compiled with great care and is believed to be correct at the date of print. The information in this document is subject to change without notice and does not represent a commitment on the part of OMICRON NanoTechnology GmbH.



Please note. Some components described in this manual may be optional. The delivery volume depends on the ordered configuration.



Please note. This documentation is available in English only.



Attention. Please read the safety information on pages 11 to 12 before using the instrument.



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Related Manuals
ComputerBoards GPIB Manual
CPC 125/65 M Channeltron Pulse Counting Electronics for EA 125 and AR 65
CPC 125/65 S Channeltron Pulse Counting Electronics
EAC Electronics for EA 125 Technical Reference Manual
EIS Software Manual
PHI MultiPak Software Manual
'PRESENTS' Data Presentation Package User's Guide
ISS User's Guide for EA 125
XM 500 Monochromator User's Guide

Table 1: Related manuals.

Copyright

No part of this manual may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying and recording, for any purpose without the express written permission of OMICRON NanoTechnology GmbH

Warranty

OMICRON acknowledges a warranty period of 12 months from the date of delivery (if not otherwise stated) on parts and labour, excluding consumables such as filaments, sensors, etc.

No liability or warranty claims shall be accepted for any damages resulting from non-observance of operational and safety instructions, natural wear of the components or unauthorised repair attempts.

Normal Use

The **EA 125 Energy Analyser** is an electrostatic analyser for measuring the kinetic energy of electrons arising from photo-emission experiments, e.g. XPS, UPS, XPD, Auger and ions from ion-scattering spectroscopy (ISS) experiments.

The **EA 125 Energy Analyser** shall always be used

- in conjunction with an EAC 2000-125 or EAC 300-125 control unit
- inside a suitable vacuum chamber (explicitly specified for this purpose)
- in high vacuum, i.e. base pressure $< 10^{-5}$ mbar
- with original cable sets which are explicitly specified for this purpose
- with all cabling connected and secured, if applicable
- with all electronics equipment switched on.
- in an indoor research laboratory environment
- by personnel qualified for operation of delicate scientific equipment
- in accordance with all related manuals.



Please note: The EA 125 Energy Analyser should always be used with mu-metal shielding around the analysis area. Otherwise it might not meet the specified performance figures. This particularly applies to low energy UPS and Auger applications, i.e. kinetic energies below 200 eV.



Warning: Lethal Voltages!!

Adjustments and fault finding measurements as well as installation procedures and repair work may only be carried out by authorised personnel qualified to handle lethal voltages.



Attention: Please read the safety information in the relevant manuals before using the instrument.

Conditions of CE Compliance

OMICRON instruments are designed for use in an indoor laboratory environment. For further specification of environmental requirements and proper use please refer to your quotation and the product related documentation (i.e. **all** manuals, see individual packing list).

The OMICRON **SPECTALEED** complies with CE directives as stated in your individual delivery documentation if used unaltered and according to the guidelines in the relevant manuals.

Limits of CE Compliance

This compliance stays valid if repair work is performed according to the guidelines in the relevant manual and using original OMICRON spare parts and replacements.

This compliance also stays valid if original OMICRON upgrades or extensions are installed to original OMICRON systems following the attached installation guidelines.

Exceptions

Omicron **cannot** guarantee compliance with CE directives for **components** in case of

- changes to the instrument **not authorised by OMICRON**, e.g. modifications, add-on's, or the addition of circuit boards or interfaces to computers supplied by OMICRON.

The customer is responsible for CE compliance of entire **experimental setups** according to the relevant CE directives in case of

- installation of OMICRON components to an on-site system or device (e.g. vacuum vessel),
- installation of OMICRON supplied circuit boards to an on-site computer,
- alterations and additions to the experimental setup not explicitly approved by OMICRON

even if performed by an OMICRON service representative.

Spare Parts

Omicron spare parts, accessories and replacements are not individually CE labelled since they can only be used in conjunction with other pieces of equipment.



Please note: CE compliance for a combination of certified products can only be guaranteed with respect to the lowest level of certification. Example: when combining a CE-compliant instrument with a CE 96-compliant set of electronics, the combination can only be guaranteed CE 96 compliance.

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1. Introduction

EA 125 Spectrometers

This manual is a guide to the installation, setting to work and operation of the vacuum, electronic and computer hardware for an EA 125 Energy Analyser and includes information on experimental procedures to assist the new user.

The EA 125 Energy Analyser forms part of a complete EA 125 hemispherical spectrometer system for XPS, AES, UPS, ISS and synchrotron applications, featuring an energy resolution better than 10 meV (FWHM) (6 meV in the high resolution EA 125 HR versions), a multi-element universal lens with selectable analysis area and acceptance angle, Channeltron[®] pulse counting with >10 Mcps count rate per channel, a kinetic energy range up to 2000 eV and data acquisition and analysis software. More detailed information about the channeltron detection systems, electronics, computer hardware and software may be found in the related manuals in Table 1, on page 2.

Throughout this manual the word electrons is used to denote electrons or ions unless the description specifically relates to electrons, such as in the section on the operation of the channeltron electron multipliers.

EA 125 Vacuum Hardware

The vacuum hardware of the EA 125 Energy Analyser comprises:

1. a multi-element electrostatic lens with 30 mm working distance, to collect electrons from the sample and focus them on the entrance of the hemispherical energy analyser. The lens may also accelerate or retard the electrons relative to the energy at which they left the sample and provide variable magnification and angular acceptance to select the sample analysis area,
2. a set of slits at the entrance to the energy analyser to alter the transmission characteristics and resolution of the analyser,
3. a hemispherical energy analyser with 125 mm mean radius 180° double focusing geometry,
4. a set of slits at the exit of the energy analyser corresponding to the number of electron multipliers in the detector, and
5. a detector consisting of an array of 1, 5 or 7 Channeltron[®] electron multipliers.

The hemispherical energy analyser is mounted on a stainless steel flange under a hemispherical stainless steel cover, see Figure 1. Magnetic shielding is provided by 1 layer (or 2 layers in the EA 125 HR) of mu-metal shielding within the stainless steel flange and cover. The EA 125 Energy Analyser is mounted on the vacuum system by a NW 100 CF (6" OD) flange.

Versions of the EA 125

Four versions of the EA 125 and EA 125 HR Energy Analysers are available:

- EA 125 U1 with a single detector which cannot be further upgraded.
- EA 125 U7/1 with a single detector which can be upgraded to a 7 channel detector.
- EA 125 U7/5 with a 5-channel detector which can be further upgraded.
- EA 125 U7 with a 7-channel detector which cannot be further upgraded.

Computer Operation

The operations of the lens, analyser and detector are controlled via an IEEE interface from a PC based computer to an EAC 2000-125 or EAC 300-125 spectrometer control unit. The IEEE interface is in turn controlled by EIS (Electron and Ion Spectroscopy) Software which also acts as the communication link between the user and the computer. This software also communicates with a SAC counter board and processes the signal. Both the IEEE board and the SAC counter board reside in the computer.

EA 125 Energy Analyser Computer Requirements

The recommended minimum computer requirements for the operation of EIS (Electron and Ion Spectroscopy) Software for use with the EA 125 analyser are as follows:

- IBM PC compatible computer
- Two (2) spare PCI slots (for full length cards)
- 200 MHz Pentium or Celeron processor
- 64 MB memory
- 4 GB HDD (EIS uses approximately 10 MB)
- SVGA graphics (1024x768 capable)
- 17 inch monitor
- Microsoft Windows NT[®] 4.0 operating system

Hardcopy output is supported to any Windows NT[®] compatible device

The SAC and IEEE interface cards fit into spare expansion slots of the host computer. The SAC requires a PCI slot. The slot should be at least 120 mm tall with a depth of at least 240 mm. The ComputerBoards IEEE interface card requires that the PCI slot should be at least 120 mm tall.

2. Safety Information



Important:

- Please read this manual and the safety information in all related manuals before installing or using the instrument.
- Please read this manual and the safety information in all related manuals before installing or using the electronics equipment.
- The safety notes and regulations given in this and related documentation have to be observed at all times.
- Check for correct mains voltage before connecting any equipment.
- Do not cover any ventilation slits/holes so as to avoid overheating.
- The EA 125 Energy Analyser may only be handled by authorised personnel.



Warning: Lethal Voltages!!

- Adjustments and fault finding measurements may only be carried out by authorised personnel qualified to handle lethal voltages.
- Lethal voltages are present inside the filtered plug, EAC 2000-125, EAC 300-125 and parts of the instrument during operation.
- Lethal voltages are present at unconnected plugs.



Always

- All connectors which were originally supplied with fixing screws must always be used with their fixing screws attached and tightly secured.
- Always disconnect the mains supplies of all electrically connected units before
 - ⇒ venting, pumping down or opening the vacuum chamber
 - ⇒ opening a control unit case,
 - ⇒ touching any cable cores or open connectors,
 - ⇒ touching any part of the in-vacuum components.
- Leave for a few minutes after switching off for any stored energy to discharge.



Venting

- Make sure all parts of the EA 125 Energy Analyser have gained room temperature and disconnect all cables from the base flange before venting the vacuum chamber.



Never

- Never exceed a pressure of 1.1 bar inside the vacuum chamber.
- Never have in-vacuum components connected to their electronics in the corona pressure region, i.e. between 10 mbar and 10^{-3} mbar, so as to avoid damage due to corona discharge.



This product is only to be used:

- within a dedicated UHV system
- under ultra-high-vacuum conditions
- indoors, in laboratories meeting the following requirements:
 - ⇒ altitude up to 2000 m,
 - ⇒ temperatures between 5°C / 41°F and 40°C / 104°F (specifications guaranteed between 20°C / 68°F and 25°C / 77°F)
 - ⇒ relative humidity less than 80% for temperatures up to 31°C / 88°F (decreasing linearly to 50% relative humidity at 40°C / 104°F)
 - ⇒ pollution degree 1 or better (according to IEC 664),
 - ⇒ overvoltage category II or better (according to IEC 664)
 - ⇒ mains supply voltage fluctuations not to exceed $\pm 10\%$ of the nominal voltage

3. The Hemispherical Analyser

The EA 125 is based on a 125 mm mean radius electrostatic hemispherical deflection analyser composed of two concentric hemispheres. The inner and outer hemispheres are biased negative and positive with respect to the pass energy of the analyser. The analyser disperses electrons according to their energy across the exit plane (between the two hemispheres) and focuses them in the angular dimension, from the entrance to the exit plane.

Variable slits are located at the entrance and exit of the analyser. These are selected and changed by means of external rotary feedthroughs. For the non-upgradable single channel version the entrance and exit slits are coupled and can be controlled by a single rotary feedthrough.

A schematic of a multi-channel EA 125 is shown in Figure 1.

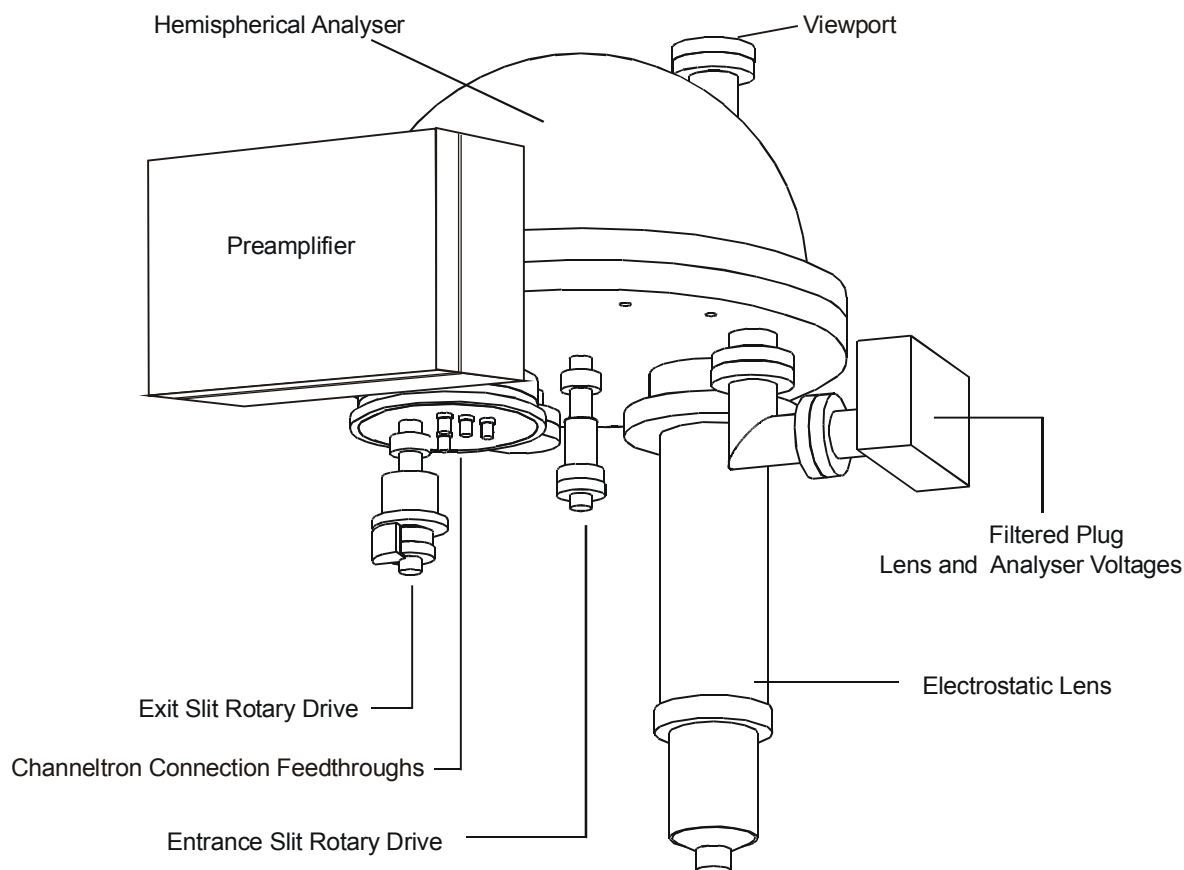


Figure 1. The EA 125 hemispherical analyser major components. Preamplifier to Channeltron connection cables not shown.

Jost field correctors are used to provide accurate field termination at the entrance and exit planes. A hole in the outer hemispherical detector is used as a beam dump for high energy electrons and as a facility which permits the sample to be viewed (and aligned) through the lens stack.

The analyser can be operated in Constant Analyser Energy mode (CAE mode) or Constant Retard Ratio mode (CRR mode).

The Electrostatic Input Lens

The input lens collects the electrons from the source and focuses them onto the entrance aperture of the analyser whilst simultaneously adjusting their kinetic energy to match the pass energy of the analyser. The lens is also designed to define the analysis area and angular acceptance of electrons which pass through the hemispherical analyser.

The lens design employs a double lens concept whereby two lenses are stacked one above the other.

The first lens (as seen from the sample) selects the analysis area (spot size) and angular acceptance. This is an Einzel lens, i.e. it does not change the energy of the electrons and therefore has a constant magnification throughout the entire energy range. This lens can be operated in three discrete magnification modes: high, medium and low. In high magnification mode, the focal plane is near to the sample and the lens accepts a wide angle of electron beams from a small region. In low magnification mode, the focal plane is further from the sample and the lens accepts only a small angle of beams but from a larger area. The medium magnification mode is in-between the two.

The second lens retards or accelerates the electrons to match the pass energy of the analyser and uses a zoom lens function to ensure that the focal point remains on the analyser entrance aperture. The magnification of this lens varies with retard ratio (and therefore kinetic energy in CAE mode) as a result of the law of Helmholtz-Lagrange.

The analysis area is defined by the combination of the selected analyser entrance aperture and the magnification of the entire lens. The magnification of the entire lens is a product of the magnifications of the two discrete lenses.

The angular acceptance is defined solely by the selected magnification mode. This is limited by physical apertures in the lens and therefore remains nearly constant throughout the entire energy range.

UNIVERSAL LENS			
magnification mode	magnification	angular acceptance	analysis area (diameter) for 6 mm \varnothing entrance aperture
high	$\times 5$	$\pm 8^\circ$	<1.5 mm
medium	$\times 2$	$\pm 4^\circ$	3.0 mm
low	$\times 1$	$\pm 1^\circ$	6.0 mm

Table 2. Lens specifications, universal lens.

Note that the spot sizes are defined as FWHM of an approximately Gaussian profile. Due to the law of Helmholtz-Lagrange the magnification varies slightly with the retard ratio. A small retard ratio means in general a smaller magnification (larger spot size) and a higher angular acceptance. The values given in Table 2 are an average, valid for a retard ratio range from about <5 to >100 covering most applications.

The Detector

One, five or seven channel electron multipliers (Channeltron[®]s) are placed across the exit plane of the analyser. The Channeltron amplifies the current of a single electron/ion by a factor of about 10^8 . The small current pulse present at the output of the Channeltron is passed through a vacuum feedthrough and then directly into the preamplifier. From here the signal is passed on to a pulse counter for processing and production of an electron/ion energy spectrum. For further details on the detection electronics please refer to the CPC 125/65 M or S electronics manuals listed in Table 1 on page 2.

The Variable Slit Mechanism

Non-upgradable Single Channel EA 125 U1

The variable slit mechanism used with a single Channeltron is provided with five different linked pairs of entrance and exit apertures. The pairs of apertures can be selected from outside the vacuum system by a rotary drive which moves the slit plates through a rack and pinion. Table 3 below gives the standard aperture combinations.

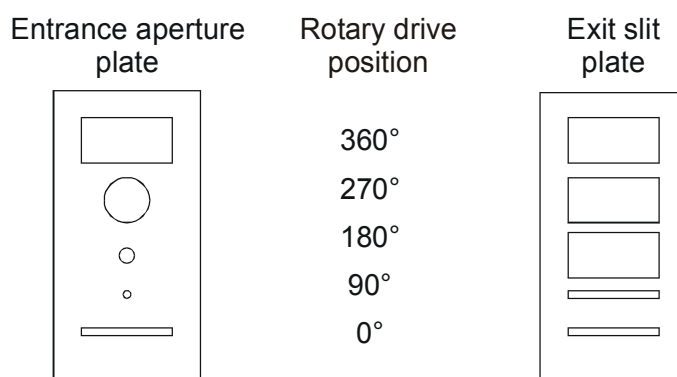


Figure 2. EA 125 U1 entrance and exit plates layout.

Single Channel Detection (non-upgradable)		
Rotary drive position	Entrance aperture dimensions	Exit slit dimensions
360°	6 mm x 12 mm	6 mm x 12 mm
270°	6 mm diameter	6 mm x 12 mm
180°	2 mm diameter	6 mm x 12 mm
90	1 mm diameter	1 mm x 12 mm
0	1 mm x 12 mm	1 mm x 12 mm

Table 3. EA 125 U1 standard aperture combinations

Multi-channel Analyser EA 125 U7

Upgradable Analysers EA 125 U7/1 and /5

The entrance and exit slit mechanisms in seven channel and upgradable systems can be operated independently to give a wide range of combinations. The entrance and exit slit arrays have separate, independent rotary drive mechanisms.

The entrance apertures are identical to those in the non-upgradable version.

The exit apertures consist of 3 sets of 7 apertures, one for each of the 7 possible channeltrons. Table 4 below gives the standard aperture dimensions.

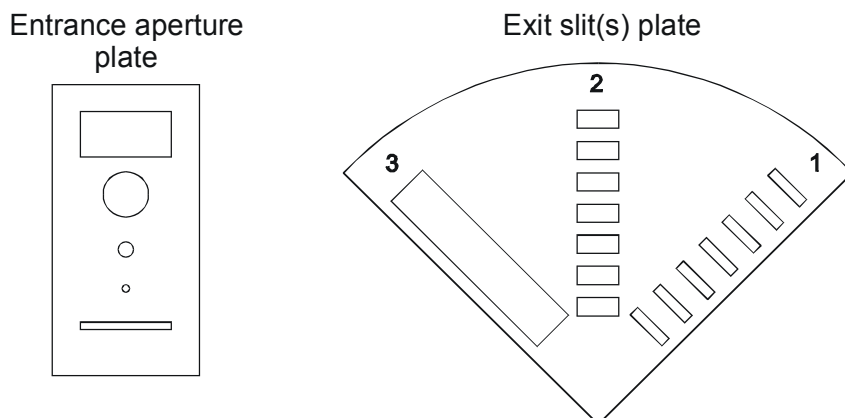


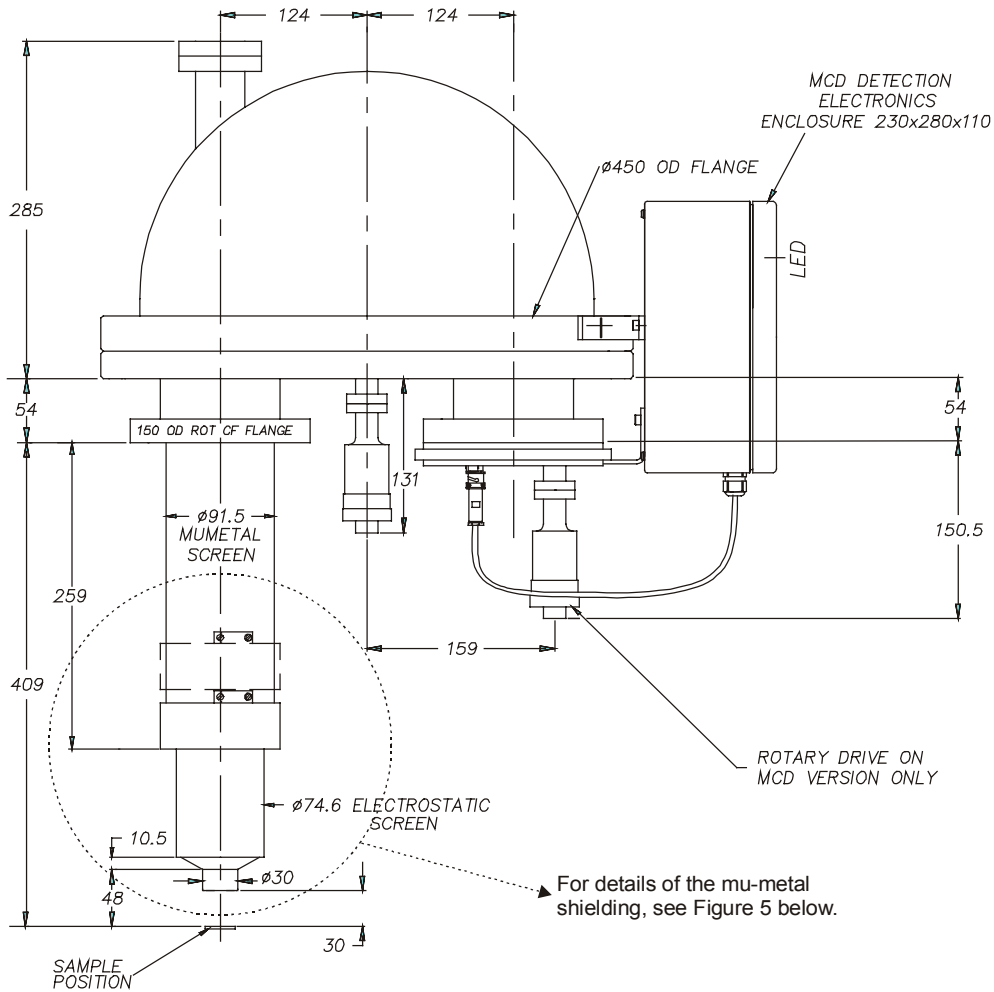
Figure 3. Multi-channel detection entrance and exit plates layout.

Multi-channel detection (7 channel and upgradable analysers)			
Analyser Entrance		Analyser Exit	
Rotary drive position	Entrance aperture dimensions	Position	Exit slit dimensions
360°	6 mm x 12 mm	1	1 mm x 10 mm
270	6 mm diameter	2	3 mm x 10 mm
180°	2 mm diameter	3	5 mm* x 11 mm
90°	1 mm diameter	*The 5 mm dimension in Position 3 reflects the width of the focus plate aperture and channeltron entrance behind the exit slit.	
0°	1 mm x 12 mm		

Table 4. EA 125 multi-channel analyser standard aperture combinations.

If a 6 mm entrance slit and a 1 mm exit slit are selected then an effective slit width may be calculated by taking the average of the two widths (i.e. 3.5 mm) to determine the analyser resolution (see also section Peak Width Measurement on page 48).

Outline Dimensions




EA125 ANALYSER WITH LENS SCREENS
FOR STANDARD OMICRON MUMETAL CHAMBERS

Figure 4. Analyser with Universal Lens, all dimensions in mm. The standard length of the mu-metal screen is 259 mm

Magnetic Shielding

For optimum energy resolution the EA 125 analysers are provided with one layer (or two layers for HR versions) of mu-metal shielding around the input lens and the analyser hemispheres to prevent magnetic field penetration into the analyser. Preferably, the analyser should be mounted in a mu-metal chamber and a strip of mu-metal formed into a spiral is provided for the user to fit between the input lens mu-metal cover and the analyser mounting port. The mu-metal spiral completes the magnet circuit between the analysis chamber and the lens cover to minimise magnetic field penetration into the analysis space.

If the user has a stainless steel chamber, the mu-metal cover for the input lens is extended almost to the end of the lens and a mu-metal spiral is not provided.

 **Please note:** The energy resolution of High Resolution (HR) analysers cannot be guaranteed if fitted to a stainless steel chamber.

For details on fitting the mu-metal spiral, see page 22.

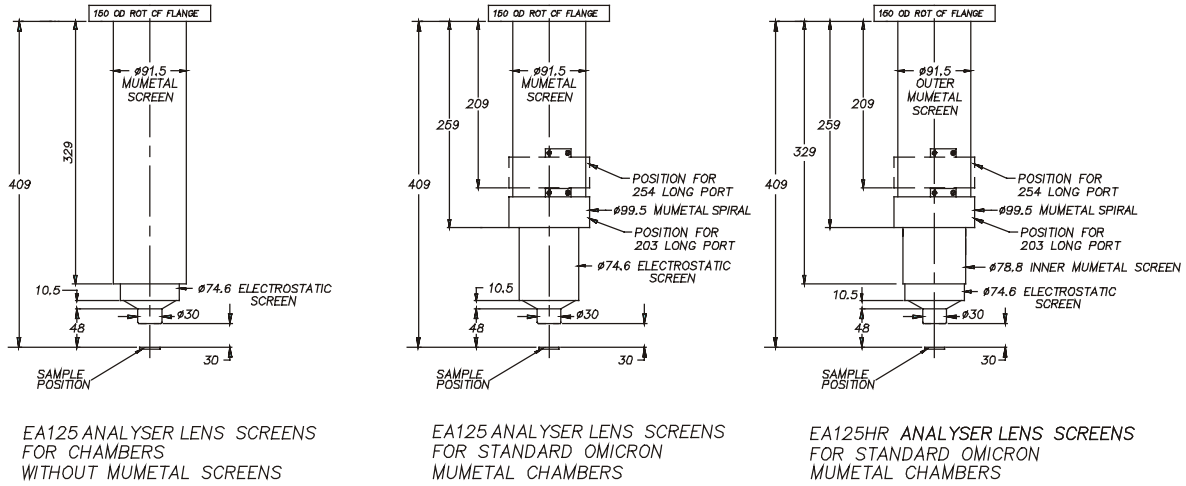


Figure 5. Mu-metal shielding for EA 125 and EA 125 HR analyser lens, all dimensions in mm.

4. Unpacking and Installation

EA 125 Analyser Supplied as a Component



Please note: This Chapter is intended primarily for the user supplied with an EA 125 analyser as a component but the information will be useful to all users who have to remove an EA 125 from a system and subsequently refit it.

The EA 125 analyser vacuum hardware is shipped on a four wheeled shipping frame and contained in a wooden crate (88 cm × 72 cm × 110 cm, 165 kg), separate from the electronics crate (83 cm × 78 cm × 67 cm, 72 kg).



Attention. All OMICRON instruments have been carefully packed before leaving the factory. Before unpacking please inspect the transport case for damage. If any damage can be seen or a rattling noise can be heard when moving the boxes **do not unpack** and contact your local OMICRON agent **immediately!**



Please note: All parts are clean to vacuum standards.

- Always use suitable polythene or cotton gloves for handling.
- Lift the analyser only by the large flange using the supplied handles.
- Take great care when unpacking, especially of ceramic feedthroughs.

Do not rest the analyser on ceramic feedthroughs or on the viewport.

Unpacking

- Remove the top and one side of the wooden crate by carefully unscrewing all screws. Inside the crate, the analyser is mounted on a metal shipping frame.

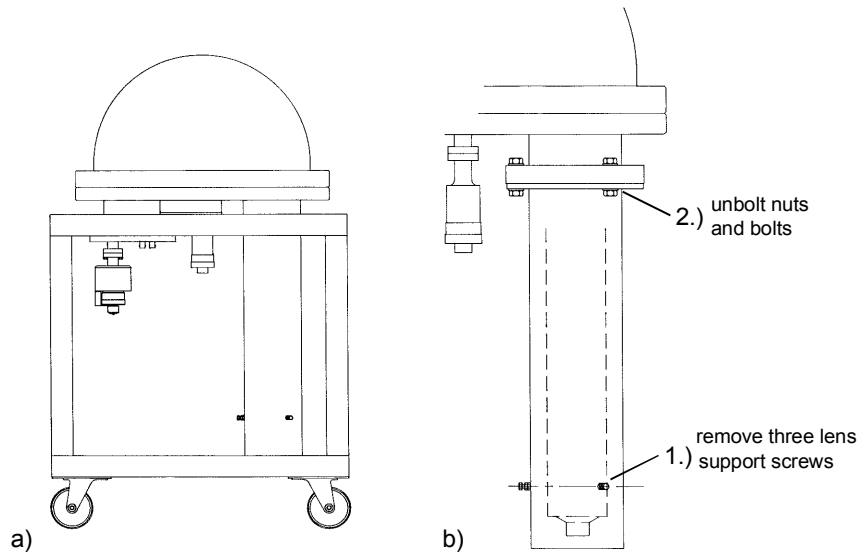


Figure 6. EA 125 shipping arrangement. a) Shipping frame. b) Detail: input lens protection tube.

- Lift the shipping frame together with the analyser out of the wooden crate (two people needed). **Caution: grasp the shipping frame, not the analyser!**
- **Check for completeness** using the enclosed packing list.
- Do a thorough visual **check for any accidental transport damage**.
- Keep the analyser in its protective packaging until it can be directly bolted onto the system.



Attention. After unpacking, keep the analyser frame and lens cover safely stored for use if the analyser has to be removed from the system.

Electrical Check

Before fitting the analyser to the vacuum system check that there are no short circuits between any channeltron and front bias feedthroughs and 9-way feedthrough pins and that none of them are connected to any external part of the EA 125 vacuum hardware. For information on the internal connections see Figures 12 and 13 on pages 31 and 32.

Vacuum Installation (and Removal)



Please note: These instructions should also be studied before **removing** the analyser from a system.

The analyser weighs some 65 kg and should therefore be supported by a suitable frame when mounted on the UHV system. The support could use the two lifting handles (two 150 mm lengths of stainless steel rod with knurled grips) screwed into the two M12 tapped

holes provided in the edge of the base flange, see Figure 7. Alternatively a support could use the four M10 × 15 tapped holes in the base plate.

Suitable lifting equipment should be available for lifting the analyser by attaching three chains to the eye-bolts provided.

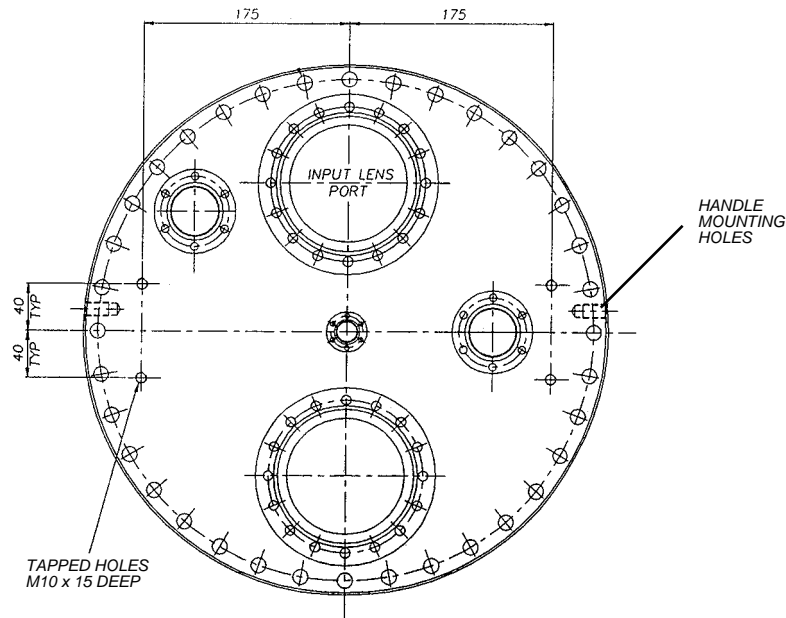


Figure 7. Mounting holes of the EA 125 analyser.



Please note: All parts are clean to vacuum standards. Always wear suitable polythene or cotton gloves and use clean, non-magnetic tools.

To install the EA 125 analyser to your vacuum system, please follow the steps below:

1. After unpacking please wait until all parts have gained **room temperature**.
2. Screw the two lifting handles into the M12 tapped holes in the outer edge of the analyser base flange.
3. Use the lifting handles to fix the crane chains to the analyser or remove 3 of the bolts which hold the analyser dome to the base flange and replace them with suitable lifting eye-bolts.



Attention. The analyser's centre of gravity is off-centre so it will tilt if not held firmly. Guide the analyser by carefully pushing the base flange to keep the lens in a vertical orientation.

4. Unbolt the four M10 bolts which hold the analyser to the support bracket on the shipping frame. Use a crane to carefully lift the analyser out of the frame while simultaneously holding it firmly.
5. With the analyser suspended remove the three lens support screws which retain the input lens protection tube, see Figure 6. Then

unbolt the nuts and bolts which hold the tube to the rotatable flange of the spacing collar and remove the input lens protection tube.

6. Fit the spacer to the rotatable mounting flange on the analyser rather than fitting it to the UHV chamber as this makes inserting the lens easier. The spacer also has a rotatable flange for use in connecting it to the vacuum chamber. It is recommended that initially both of these flanges are only loosely assembled until the analyser is correctly positioned.
7. If the analyser is to be fitted to a mu-metal chamber, use the two screws to fix the provided mu-metal spiral to the appropriate position on the mu-metal lens cover. The position of the mu-metal spiral depends on the port length to which the analyser is to be fitted as shown in Figure 8. Note that the mu-metal spiral will be in contact with the mu-metal port tubulation when the analyser is fitted to the system.

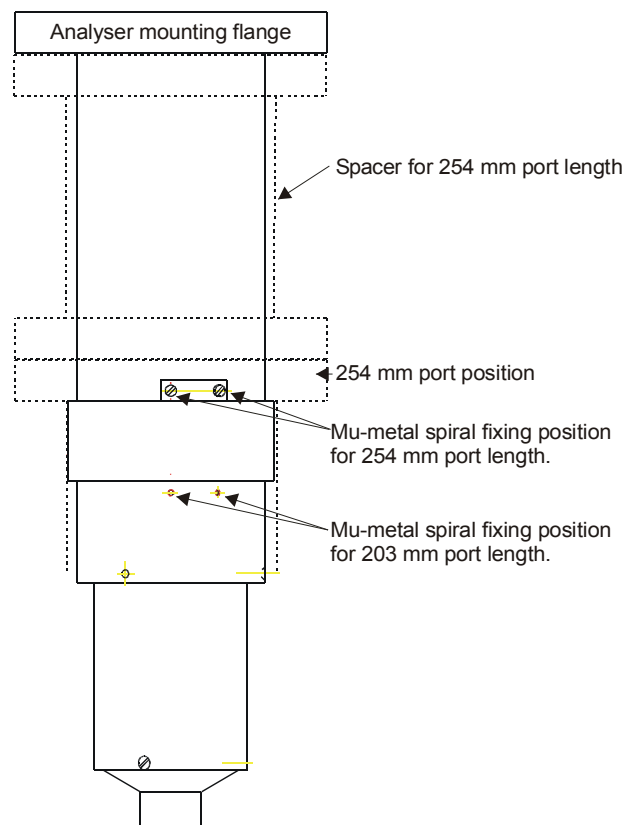


Figure 8. Mu-metal spiral positions.

8. Check that the spacer provided brings the lens stack to the correct working distance for the lens/analyser type. Supporting lugs are provided on the analyser base flange to assist when lifting the analyser to the vacuum vessel.
9. Check that the lens assembly cannot clash with other vacuum fixtures.
10. The mu-metal spiral may need to be tightened to allow it to slide freely into the end of the port. Once fitted in the port the spiral has

sufficient lateral rigidity to allow it to slide into position without bending sideways.

11. Fit the analyser to the vacuum system using a new 100 mm copper gasket and tighten the bolts evenly.
12. Evacuate the chamber to a pressure of below 10^{-5} mbar and bake the system as described on page 24.

5. Getting Started

Bakeout



Please note: Bakeout is generally recommended, but absolutely necessary only for UHV operation.

For UHV work a bakeout procedure should be performed whenever the system has been to atmospheric pressure, and at other times after extended periods at poor pressure, to improve the quality of the vacuum.



Attention. The vacuum chamber pressure must not exceed 10^{-5} mbar at any time during bakeout.

All non-bakeable items in the bakeout zone, such as cables, pipes, preamplifiers etc. should be removed prior to bakeout. Viewports and ceramic feedthroughs should be covered with aluminium foil for protection.

The recommended bakeout temperature is 180°C, recommended bakeout time is 15 hours.

Take care to avoid localised hot spots.

Allow the system to cool to room temperature before applying high voltage to the channeltrons. (The temperature of the big analyser flange can take more than 12 hours to cool to below 50°C).

Electrical Connections



Attention. After bakeout check that there are no short circuits between any channeltron and front bias feedthroughs and 9-way feedthrough pins and that none of them are connected to any external part of the EA 125 vacuum hardware earth (ground).

The complete system comprises the following units:

1. EA 125
2. EAC 2000-125 (optional EAC 300-125)
3. Channeltron[®] multiplier power supplies
4. Pulse preamplifier
5. Receiver
6. PC with EIS software.

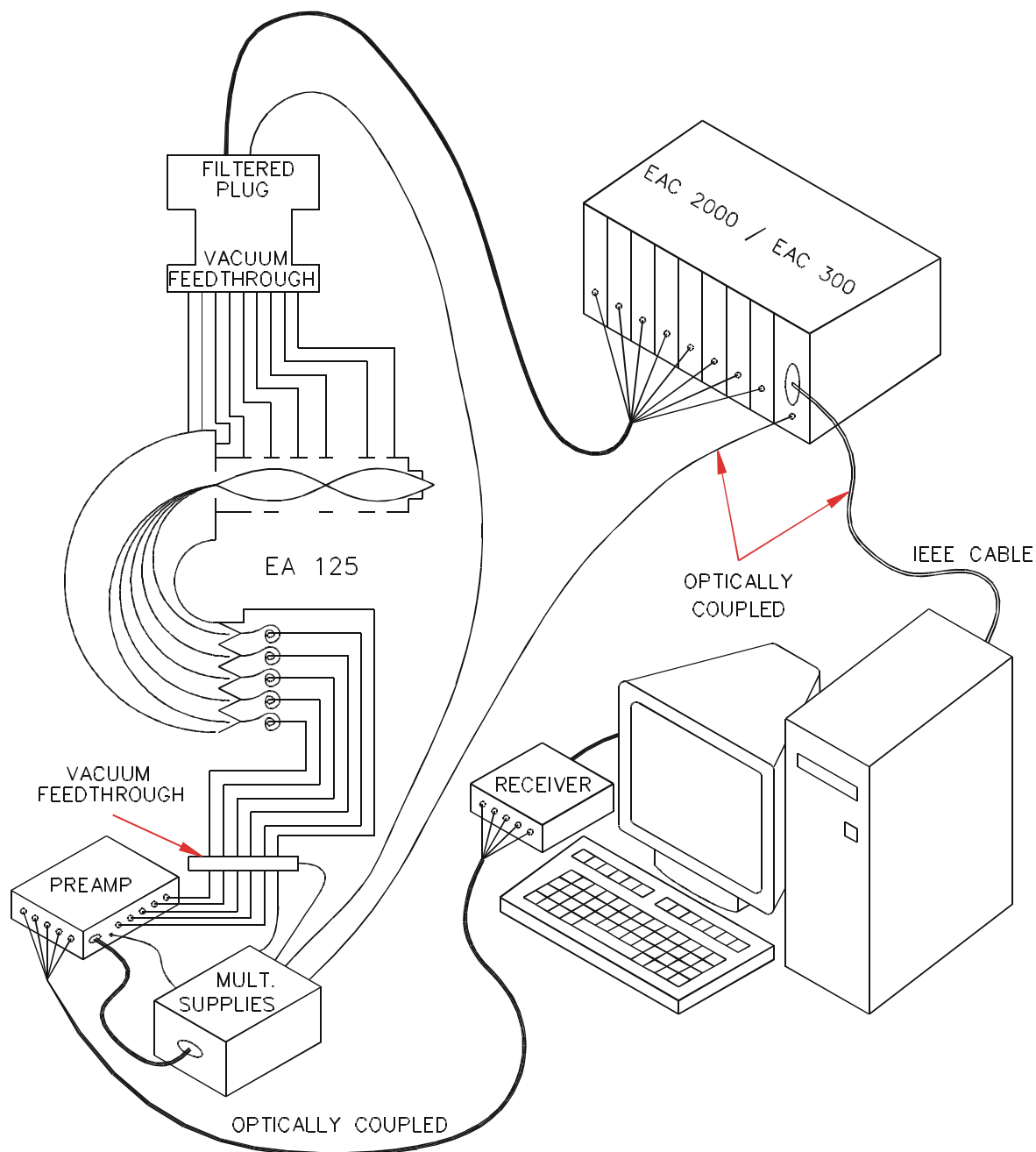


Figure 9. Electronics wiring overview for EA 125.

The Channeltron[®] multiplier power supply unit generates up to 3.6 kV and is switched ON/OFF remotely from the EAC 2000 / 300 with "slow start up". This link is optically (de-)coupled.

A pulse preamplifier detects electron pulses and filters out the system ground noise using a high speed comparator circuit with adjustable threshold for background noise rejection. The electrical signal is converted to an optical signal within the preamplifier unit and then transmitted to the receiver via a 5 m long optical fibre link.

Both pulse (TTL) and analogue signal outputs are provided. The digital (TTL) output pulses are input into the pulse counter board; the analogue voltage output is proportional to count rate and is provided for a user-supplied DVM or X-Y recorder.



Attention. Installation procedures may only be carried out by authorised personnel qualified to handle lethal voltages.

Switch off all units and wait for a few minutes (for discharge of the power supplies) before connecting or disconnecting any cables.

Make sure all high voltage plugs are secured before switching any one of the electronics units on.

- Ensure all units are off and disconnected from the mains supply before making the connections as shown in Figure 9.
- Before making the connections check the resistance of all pins to each other and to earth (ground). Resistance should be infinite except across the channel electron multiplier.
- Connect all channeltron pulse counting cables according to Figure 10 for non-upgradable single channel systems and according to Figure 11 for upgradable single channel and multi-channel systems.
- Connect all other cables to the analyser, EAC power supply and computer according to their manuals.
- Ensure the preamplifier is firmly attached to the mounting on the EA 125 flange in order to be properly grounded.



Attention. All connectors which were originally supplied with fixing screws must always be used with their fixing screws attached and tightly secured.

- Plug in all units and switch on the EAC 2000 / 300 power.

Setting up the Pulse Counting Electronics



Please note: For full details for the pulse counting electronics, please refer to the CPC 125/65 M manual for upgradable and multi-channel systems and the CPC 125/65 S manual for single channel systems as listed in Table 1 on page 2.

It is advisable to bake out the vacuum system prior to operation.



Attention. Do not bake the electronics! In order to avoid severe damage to the electronics **all units and cables must be removed from the UHV system prior to bakeout.**

When operating the CPC electronics for the first time after venting, the system should be allowed to pump for at least 4 hours. Always make sure the chamber base pressure is $<10^{-5}$ mbar.



Attention. Under no circumstances should the CPC electronics be operated in conjunction with chamber pressures $>10^{-5}$ mbar!



Please note: The Channeltron[®] lifetime will be reduced when operating the CPC electronics at pressures $>10^{-7}$ mbar; this is normal for all channel electron multipliers.

Before switching on the pulse counting electronics make sure

- the mains voltage on the multiplier supplies unit is switched off
- the chamber pressure is $<10^{-5}$ mbar
- the red MULTIPLIER ON light on the front of the EAC 300 or EAC 2000 is **not** lit.

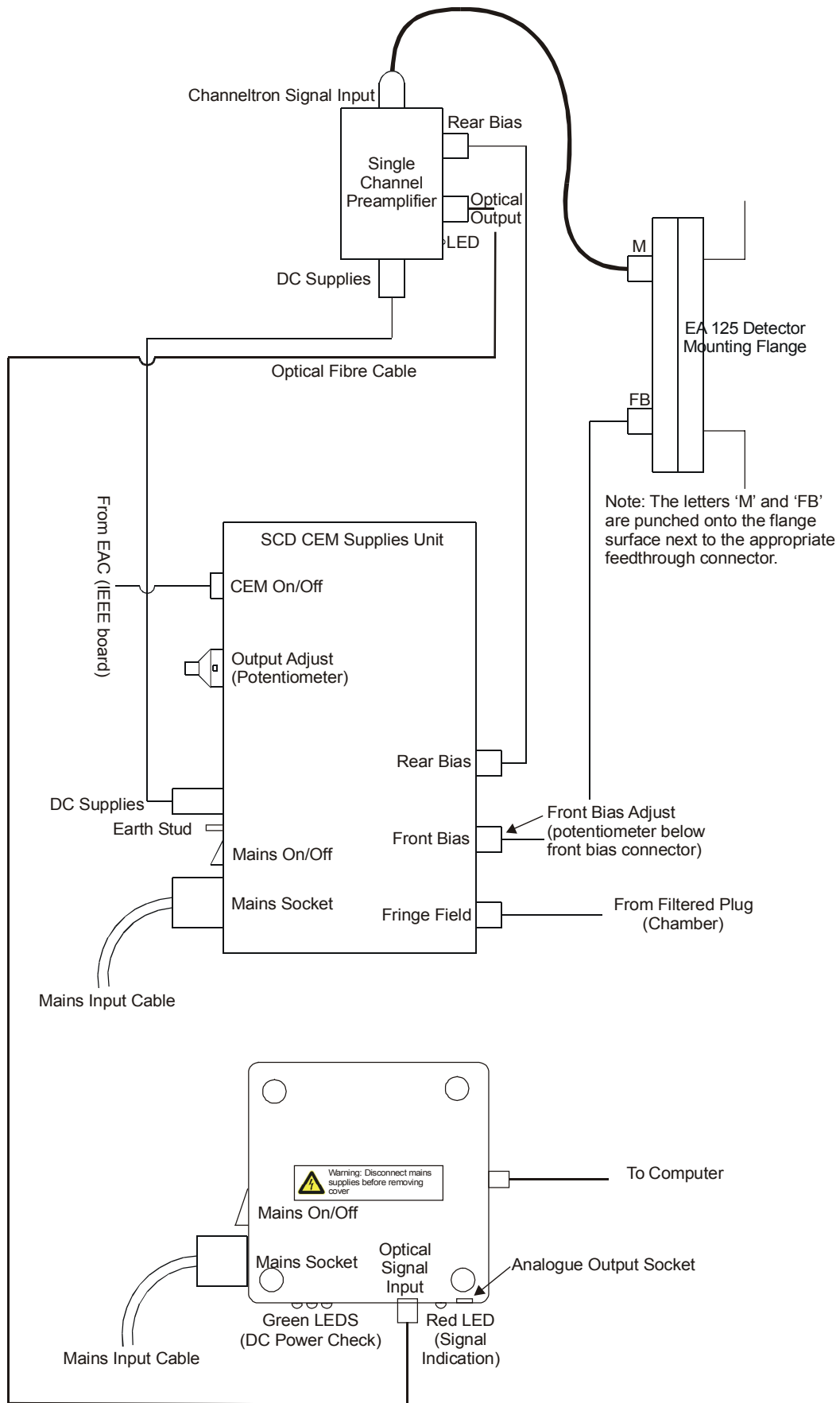


Figure 10. Connection diagram: non-upgradable single channel version.

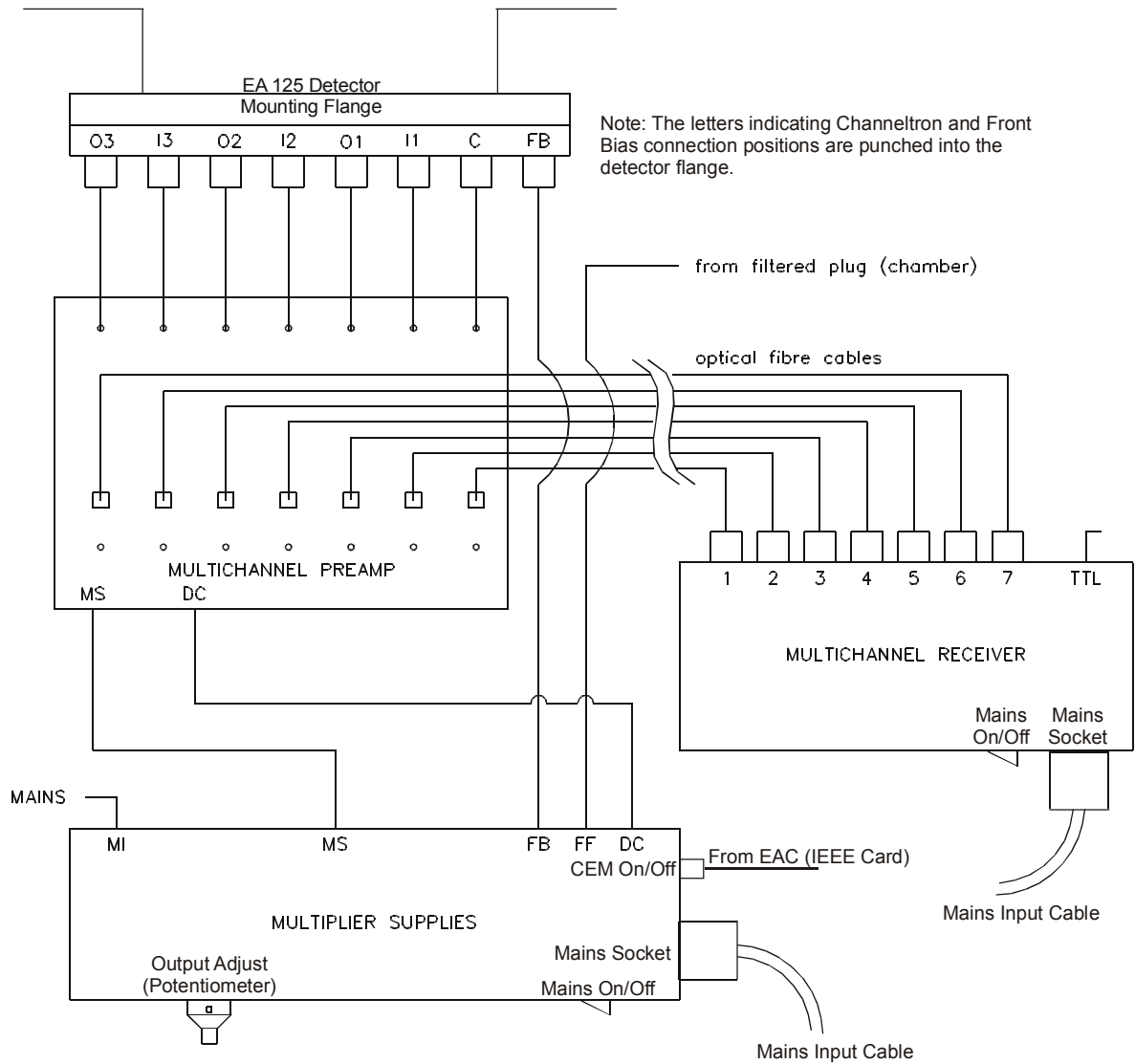


Figure 11. Connection diagram: upgradable and multi-channel detection, FB = Channeltron® front bias, C = central Channeltron® (channel 1), I1, I2, I3 = inner Channeltron®s, O1, O2, O3 = outer Channeltron®s.

Setting up the Software

Please refer to the EIS Software manual for more details.

- Fit the Omicron SAC and ComputerBoards IEEE cards into the PC.
- Install the Omicron SAC Device Driver (if necessary), the ComputerBoards GPIB Library and the EIS program from the EIS CD. The
- Shutdown and restart the computer.
- Configure the GPIB card to control an EAC 2000 or EAC 300 using the cbconf32.exe configuration program.
- Configure EIS for your system. i.e. Set the analyser, controller and detector types in the Configuration dialogue box in EIS.

For Multi-channel Analysers Only

- Set the energy dispersion factors. A print out of these is supplied with your EA 125 test data.

The software should now be set up to start a measurement. For further details on how to do this, please refer to the EIS Software manual.

6. Operation

Assuming a suitable excitation source and sample in an appropriate geometry are available, and when the vacuum pressure is below 10^{-5} mbar, the analyser is ready for operation.

Figure 12 shows the destination of the various voltages on the spectrometer. Note, however, that the spectrometer electrodes are not readily accessible as test points. All voltage checks should be carried out at the filtered plug 9-way feedthrough as shown in Figure 13. Please see the EAC 2000 or EAC 300 manuals as listed in Table 1 on page 2 for further details.

See the CPC 125/65 M (Multi-Channel) and CPC 125/65 S (Single-Channel) manuals for further details on the Channeltron pulse counting electronics.

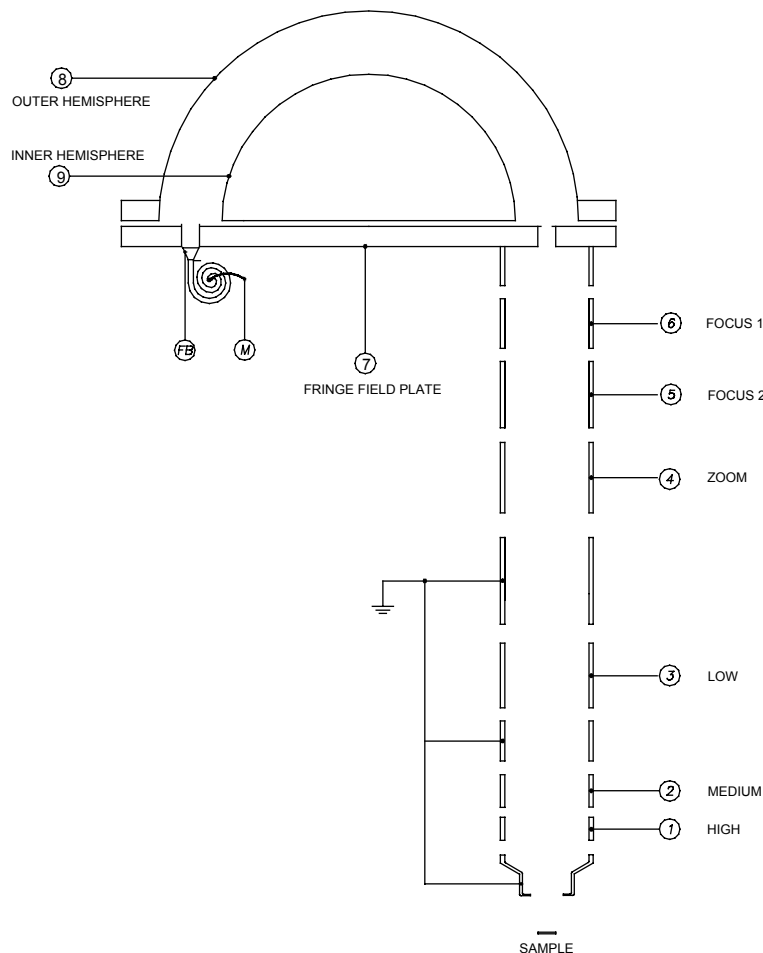
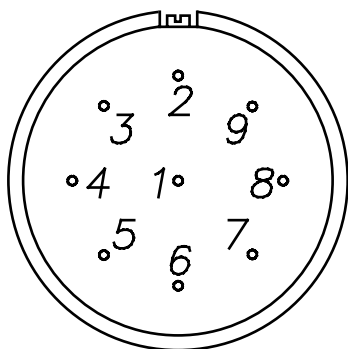


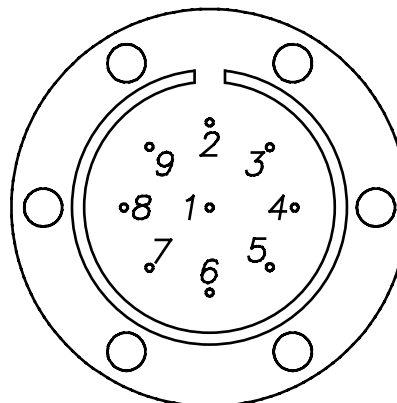
Figure 12. Internal connections. FB = Front Bias, M = Multiplier Output(s). The numbers refer to the pin numbers in Figure 13.

9-Way Plug and Feedthrough Pin Assignments.

9-WAY VOLTAGE CABLE PLUG
FOR EA 125 ANALYSER



9 WAY FEEDTHROUGH
FOR EA 125 ANALYSER



ATMOSPHERIC SIDE

Figure 13. 9-way plug and related feedthrough pin layout.

Pulse Counting Operation

- Set the 10-turn potentiometer OUTPUT ADJUST on the multiplier supplies unit to zero.
- Switch the multiplier supplies unit on.
- Switch on the receiver unit.
- Set the analyser entrance and exit slits to the largest possible settings.
- With an excitation source producing electrons from a sample, open the instrument control page in the EIS software and set a suitable pass and kinetic energy, see Chapter 4 of the EIS Software Manual.
- Switch the multipliers on and slowly apply the high voltage to the multipliers by turning the 10-turn potentiometer slowly up to the value given either on the EA set up record sheet provided with your analyser or the previously determined optimum operating value.

If at this point you see a reasonable spectrum, then proceed to optimise. If you cannot find a reasonable count indication, please refer to the Trouble Shooting section of this manual which starts on page 57.

Channeltron High Voltage Setup

Each channeltron is individually setup in the Omicron factory before shipment. As the channeltron ages however, the required operating voltage must be increased. To do this

simply increase the output adjust potentiometer on the front panel of the CEM supplies. One full turn is approximately equal to 300V. The desired operating voltage is approximately 100V above the onset of the count rate plateau (Please see the theory of pulse counting operation section of this manual). In multi-channel EAs, all channels are adjusted simultaneously with this potentiometer.



Please note: The channeltron lifetime will be reduced if the high voltage is applied at pressures $> 10^{-7}$ mbar; this is normal for all channel electron multipliers.

Multi-channel Analyser High Voltage Adjustment.

If it is suspected that any channel in a multi-channel analyser needs to be individually adjusted, please follow the procedure listed below:



Warning: Lethal Voltages!!

Adjustments may only be carried out by authorised personnel qualified to handle lethal voltages.

Lethal voltages are present inside the CEM supplies. Extreme caution should be exercised when carrying out any adjustments inside this unit.

- Pump down the system and bake the spectrometer as normal.
- Remove the CEM supplies from the equipment rack.
- Connect all cables.
- Connect a source of electrons to the spectrometer (i.e. switch on an excitation source).
- Connect a multimeter to the rate meter output of the channel in question on the receiver unit.
- Open the Instrument Control page of the EIS software
- Choose a suitable set of parameters which give around 100 kcps and enter these into the checkboxes.
- Switch ON the multiplier voltage by clicking in the Multiplier checkbox.
- Increase the front panel multiplier control dial slowly to the value at which you have been operating, observing the ratemeter output.

If the onset of the count rate plateau has not yet been reached or if you believe that the voltage is too high (count rate approaching the ionic feedback region) continue as follows:

- Remove the top panel on the CEM supplies.
- Locate the HV adjust pot on the relevant CEM HV unit (See CPC 125/65 Manual)

- Turn it counter clockwise until the count rate reduces to close to zero.
- Increase the high voltage by turning the HV adjust pot clockwise until the channeltron is operating at the desired voltage.
- Repeat for remaining channels until all channeltrons are operating at the desired voltage.
- Replace the top panel on the CEM supplies.
- Replace the CEM supplies into the equipment rack.

7. Theory of Operation

The following discussion is by no means exhaustive. It is merely meant to define the relevant parameters in analyser operation. Further details can be found in textbooks on electron spectroscopy, see page 82 for a selective list.

Radiation of wavelength $h\nu$ ejects electrons from electronic states with different binding energies in the sample leading to a range of ejected electron kinetic energies. If the sample is at earth potential, electrons ejected from a state with binding energy E_b are emitted from the sample with a true kinetic energy E_k' given by:

$$E_k' = h\nu - E_b - \phi_s$$

where ϕ_s is the work function of the sample. A schematic spectrum of electrons ejected by X-rays is shown in Figure 14.

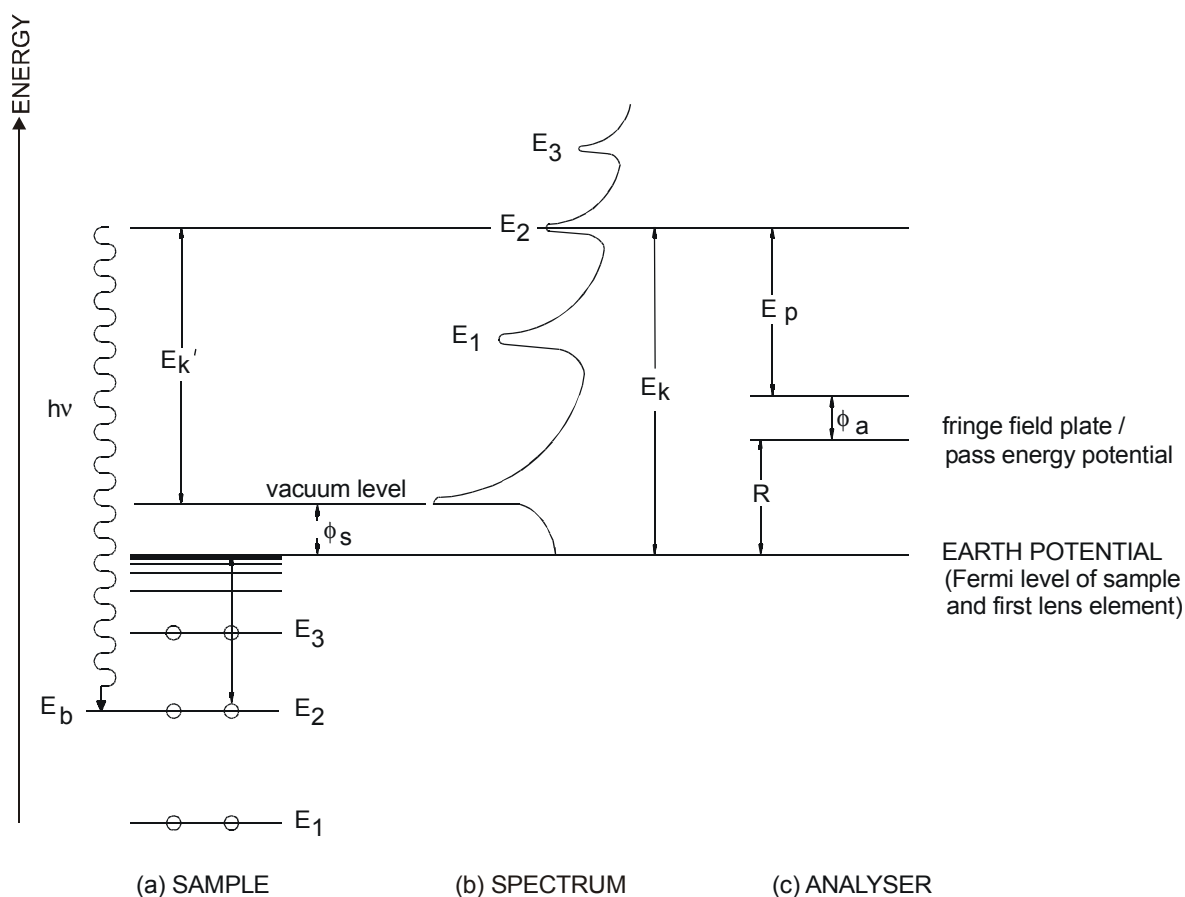


Figure 14. Workfunction of the sample and spectrum of electrons ejected by X-rays. Although the true kinetic energy of the electron leaving the sample (E_k') depends on the work function of the sample (ϕ_s), the measured kinetic energy (E_k) only depends on the work function of the analyser (ϕ_a).

The energy distribution of electrons has the following features:

- The spectrum low energy cut off is at $E_k = \phi_s$. Below this energy electrons have insufficient kinetic energy to overcome the work function of the sample (however, this may be overcome by biasing the sample).
- A large peak at low kinetic energy is due to the "true" secondary electrons.
- The centre of the spectrum has peaks corresponding to the discrete states from which the electrons are ejected.
- The high energy cut off occurs when electrons are ejected from the Fermi level where E_b is defined to be zero, i.e. at $E_k' = hv - \phi_s$.

Note that the true kinetic energy scale cannot be measured directly because ϕ_s , which varies from sample to sample, is not known; only the quantity $(E_k' + \phi_s)$ can be determined by calibration. ϕ_s can however be estimated since the spectrum cuts off at $E_k = \phi_s$.

The offset of the spectrum by ϕ_s is not as important as might be imagined since it is the kinetic energy measured with the analyser which is important. This can be seen from the following.

The ejected electrons pass through the first lens element and are then retarded by an amount R , determined by the lens voltages, before entering the analyser. The analyser is a band pass filter only transmitting electrons with energy very near to the pass energy E_p which are then stopped in the detector. Therefore the electrons have a measured kinetic energy of $R + E_p$. But note that the analyser also has a work function, ϕ_a . Therefore electrons which have been transmitted by the analyser with a retardation of R and a pass energy of E_p would have had a kinetic energy of:

$$E_k = R + E_p + \phi_a = hv - E_b$$

which is independent of the sample work function ϕ_s . Note that the software measures

$$E_k^{\text{software}} = R + E_p$$

unless you set the workfunction parameter.

A typical value of for the work function ϕ_a for the EA 125 is between 4.2 and 4.8 eV.

The Hemispherical Analyser

In the hemispherical analyser two concentric hemispheres of mean radius R_0 are mounted with the common centre of O , see Figure 15 on page 37. A potential V is applied between the surfaces so that the outer is negative and the inner positive with respect to V_0 which is the median equipotential surface between the hemispheres, and the entrance and exit slits are both centred on R_0 .

If E_p is the kinetic energy of an electron travelling in an orbit of radius R_0 (we call E_p the "pass energy"), then the relationship between E_p and V_0 is given by the expression:

$$eV_0 = E_p \cdot \left(\frac{R_2}{R_1} - \frac{R_1}{R_2} \right)$$

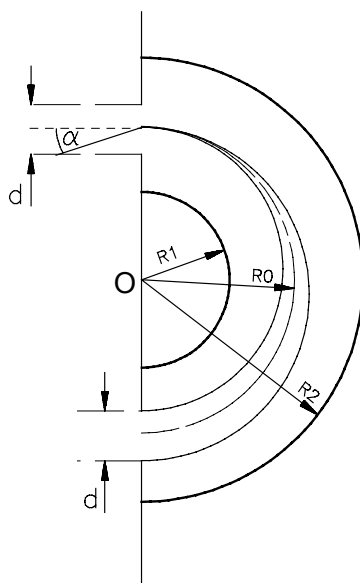


Figure 15. The hemispherical analyser, schematic diagram.

The voltages on the inner and outer hemispheres are V_1 and V_2 respectively and these are given by:

$$V_1 = E_p \cdot \left(2 \frac{R_0}{R_1} - 1 \right)$$

$$V_2 = E_p \cdot \left(2 \frac{R_0}{R_2} - 1 \right)$$

Where E_p is the mean analysing energy or pass energy of the analyser. This produces an inverse squared ($1/R^2$) field in the region between the hemispheres.

Please see reference [4] in Surface Analysis General Literature on page 82 for further details.

The Universal Lens

This section is intended as a brief introduction into the main aspects of the electron optics of the universal lens. For a detailed description, please refer to:

King, George C., 5. Electron and Ion Optics, In: *Experimental methods in the physical sciences*, Volume 29A, Academic Press Inc., 1995.

Electrostatic Input Lens

The universal lens is a multi-element electrostatic input lens fitted at the entrance to the analyser. The purpose of the lens is to allow a collection of electrons from larger solid angles than would otherwise be possible and to vary the energy of the beam to the pass energy of the analyser. The resolution obtainable with a hemispherical analyser can be significantly increased by reducing the pass energy of the analysed electrons.

The universal lens consists of 11 cylindrical electrodes held at different potentials. Close to the gap between the various elements the potential gradients generate lines of equipotential which refract charged particles crossing them. This effect is shown schematically in Figure 16 for a lens with two cylindrical electrodes.

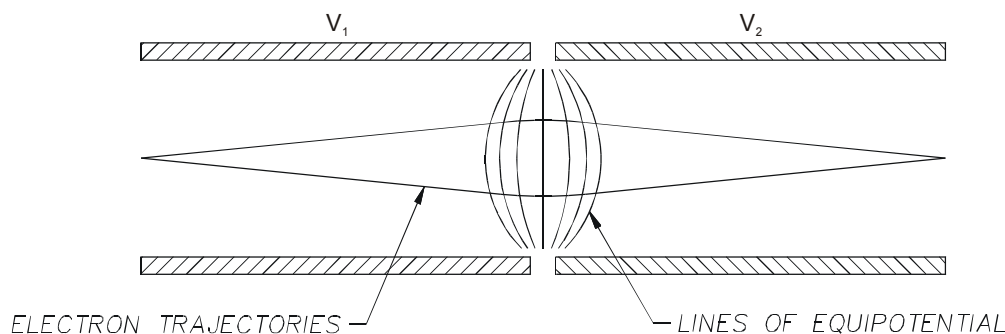


Figure 16. Trajectories in a lens with two cylindrical electrodes.

By employing a three cylinder arrangement, it is possible to accelerate or retard the electrons by varying amounts and keep the focusing properties constant. The schematic layout of a lens with three cylindrical electrodes is shown in Figure 17.

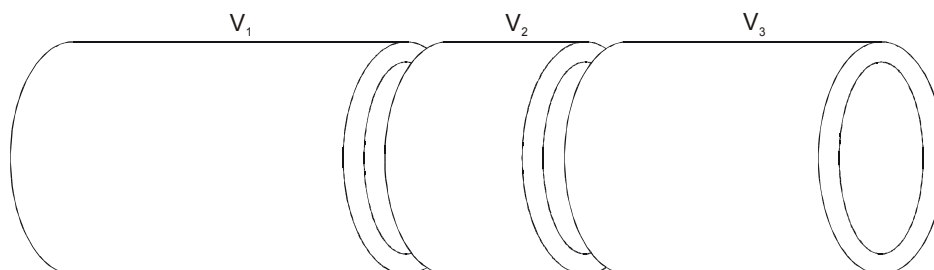


Figure 17. Lens with three cylindrical electrodes.

Einzel Lens

If the potentials applied to V_1 and V_3 in Figure 17 were equal, the three cylinder lens would not change the energy of the transmitted electrons, but there would still be a focusing effect. This arrangement is known as an Einzel lens.

This type of lens design is employed in the first stage of the Universal lens and is used to set the magnification and angular acceptance.

Zoom Lens

If the potentials applied to V_1 and V_3 are not equal, the three cylinder lens will either accelerate or retard the transmitted electrons. It is possible to calculate a range of values

which must be applied to V_2 to keep the object to image distance constant whilst varying the ratio through which the electrons are accelerated or retarded. This is known as a zoom lens curve as shown in Figure 18.

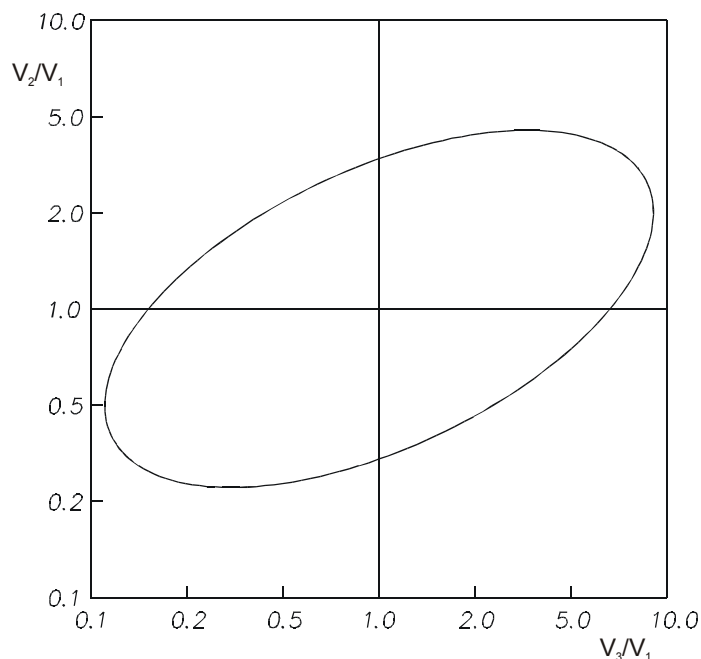


Figure 18. Zoom lens curve.

Note that for any given accelerating/retarding ratio (V_3/V_1) there are two values for V_2/V_1 which both focus the electrons to the same point.

An advanced version of this type of zoom lens design is employed in the second stage of the Universal lens and is used to set the pass energy of the analyser.

The Law of Helmholtz-Lagrange

Apertures are used in electrostatic lenses to define the beam. A window aperture defines the radial size of the beam and a pupil aperture defines the angular extent of the beam.

Figure 19 shows a schematic of an electrostatic lens produced by the different potentials V_1 and V_2 illustrating the definition of the beam by the window and pupil apertures.

The lens produces an image of the window. The radial size of the image is determined by the magnification, M , of the lens.

$M = r_2/r_1$, where r_1 and r_2 are as shown in Figure 19.

As the beam has passed from potential V_1 to V_2 , there has also been a change of energy.

The angular extent of the beam is minimised by placing the pupil at the focal length of the lens. This produces a zero beam angle and hence the angular extent of the beam is solely defined by the pencil angle (θ).

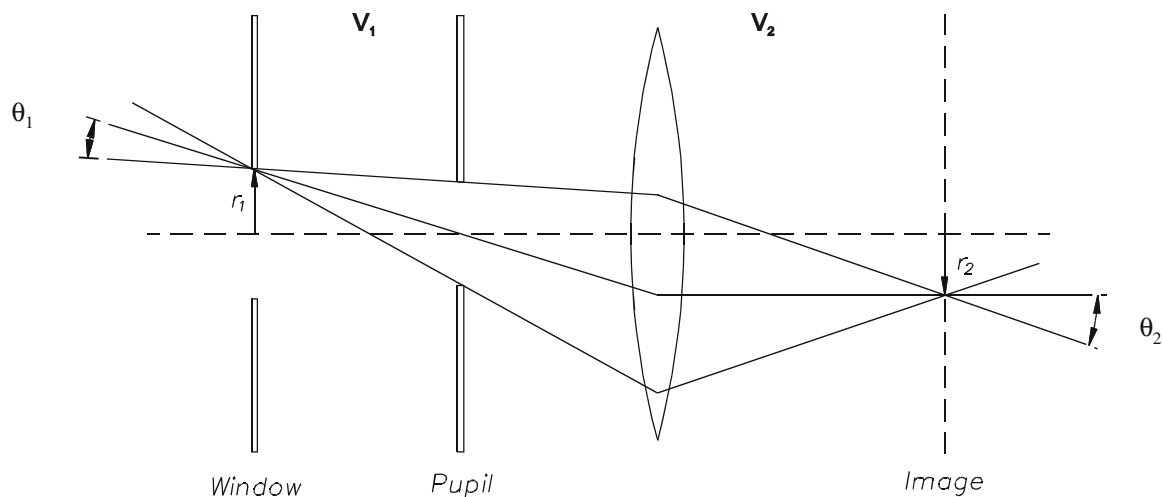


Figure 19. Lens apertures to define beam.

The quantities r , θ , and V in the object (window) and image plane are related by the law of Helmholtz-Lagrange:

$$r_1 \theta_1 V_1^{1/2} = r_2 \theta_2 V_2^{1/2}$$

The product of r , θ and $V^{1/2}$ is conserved. So, as the retarding ratio (V_1/V_2) is increased, the linear and/or angular magnification must also increase.

Pulse Counting Operation

In an electron spectrometer, electrons/ions which arrive at the input of the Channeltron[®] detector generate secondary electrons which are then accelerated down the Channeltron[®] by a positive voltage bias (+2 kV to +3 kV at the output). These electrons strike the Channeltron[®] wall producing additional electrons progressively down the Channeltron[®] to the output where between 10^7 to 10^8 electrons arrive.

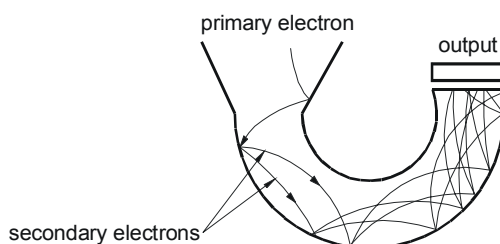


Figure 20. Electron amplification in a Channeltron[®], schematic diagram.

The statistical nature of the multiplication process results in a Gaussian distribution of pulse heights at the output from a channeltron.

Channeltron Operating Plateau

As the voltage applied to a channeltron is increased, the gain increases and the output pulse height increases. As more and more output pulses exceed the threshold set in the preamplifier, the observed count rate increases. When the gain is large enough for the smallest pulses in the distribution to exceed the threshold, a plateau is reached and no further increase in count rate is observed with higher voltages as shown in Figure 21. At very high voltages, the observed count rate again increases due to the feedback of positive ions generated within the channeltron. This should always be avoided as the observed pulses do not result from an input and operating channeltrons in this condition considerably reduces their lifetime.

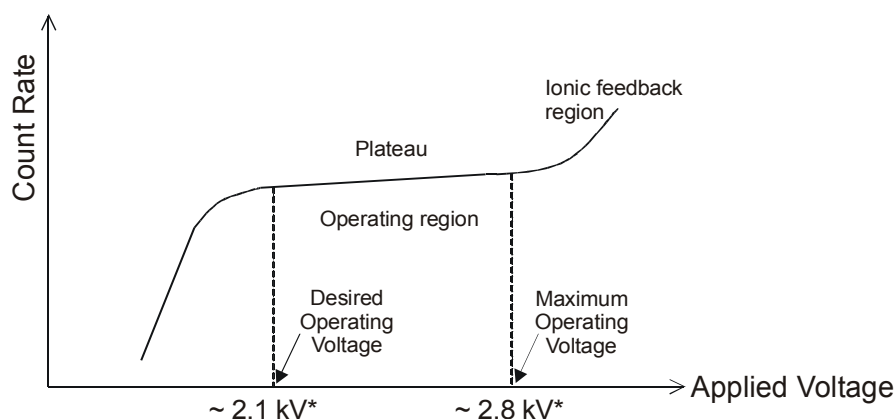


Figure 21. Channeltron operating plateau.

The onset of the plateau is reached at approximately 2 kV for new channeltrons and this slowly increases as the channeltron ages. The desired operating voltage is approximately 100V above the onset of the plateau. In Figure 21 the applied voltages marked with an *

are for new channeltrons only, the plateau onset and end voltages will rise as the channeltron ages.

The electron pulse is then routed to the preamplifier which filters out the system noise using a high speed threshold comparator circuit. The electrical signal is converted to an optical signal which is transmitted to the receiver unit via an optical fibre link. The receiver unit converts the optical signal to a TTL electronic pulse which is then counted by the computer.

The optical link isolates the pulse counting system, usually a computer, from the spectrometer and maintains low noise data levels.

The optical receiver provides both digital (TTL) output pulses for the pulse counter, and an analogue voltage which is proportional to the count rate. Normally |10 V| correspond to 1 Mcps (million counts per second). The output polarity and range are jumper selectable on each receiver board, see the CPC 125/65 M and CPC 125/65 S manuals listed in Table 1 on page 2.

Channeltron Lifetime Expectancy/Replacement

The normal behaviour of a channeltron as it ages is for the plateau voltage to steadily increase during early operation. This voltage levels out on to a plateau. After this plateau is reached the channeltron should last for a considerable period with very little increase required.

Omicron try not to significantly age channeltrons before shipping. This often means that the operating voltage will need to be gradually increased during early operation. This is normal behaviour and eventually the operating voltage should level out.

It is difficult to give a normal expected lifetime of channeltrons as their lifetime is limited by the total accumulated output charge. A figure of around 10^{12} accumulated counts should be attainable. The lifetime is also very much dependent on the environment in which they are operated and will be very much reduced in contaminated systems. Pump oil and other reactive materials are particularly harmful.

For information regarding the replacement of channeltrons, please contact Omicron Service following the procedure on page 83.

Multi-channel Analysers

The observed intensity in an analyser can be multiplied by up to a factor of seven by simply positioning extra detectors (channeltrons) at different positions in the exit plane. When the kinetic energy is scanned, these extra detectors will measure spectra which are offset in energy from the true spectra by an amount proportional to the pass energy and also to the position of the detector relative to the centre channel.

Energy Dispersion

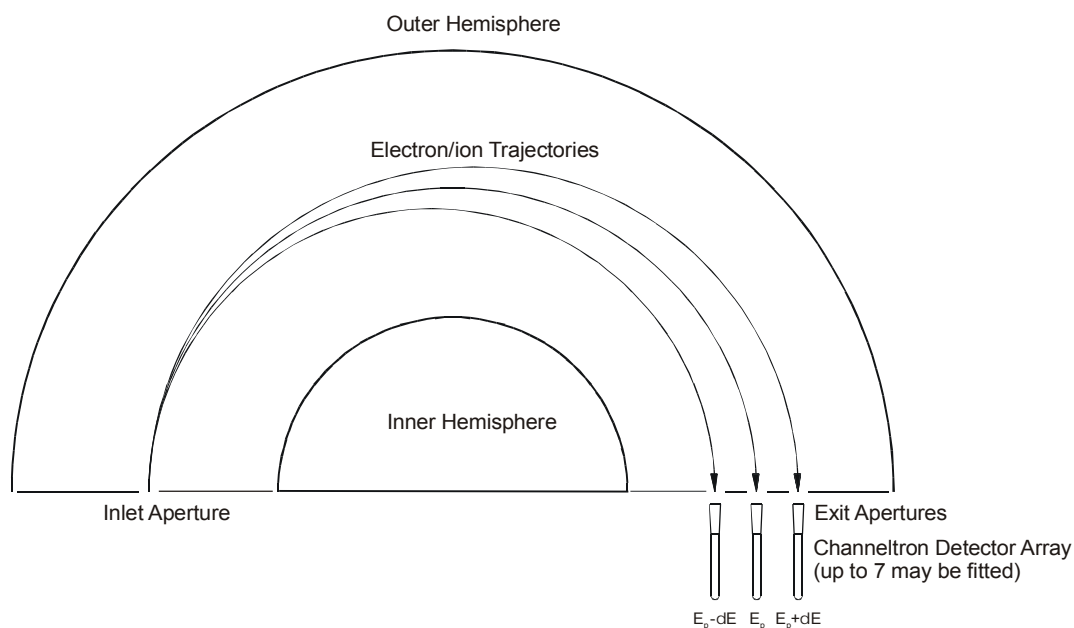


Figure 22. Multi-channel analyser energy dispersion.

The energy offset from the centre channel is equal to the pass energy multiplied by an individual dispersion factor for the position of the channeltron in the exit plane,

$$\delta E = E_p \times D$$

where δE = Energy Offset, E_p = Pass Energy and D = Dispersion Factor.

The EIS software is configured to take the energy dispersion into account when scanning in MCD mode and offset the acquired spectra by the correct amount before summing each channel. After calibration there should be no significant loss in resolution when scanning in MCD mode (compared to scanning in single channel mode).

Details of the software MCD Scanning Algorithm and details of how to calibrate the dispersion factors can be found in the EIS Software Manual.

Statistics of Counting

In the pulse counting process the maximum counting speed is limited by the following components: the channeltron, the preamplifier and the computer interface board. Special attention has been paid to extend this limit from the more common maximum of 100 kcps to a count rate of 14 Mcps as measured for periodic pulses. The following results should make clear, however, that even with such a high count rate the maximum reliable number of counts per second (i.e. with a low percentage of error) is much lower for statistical pulses. Here we will only deal with the results of more rigorous treatments that can be found in the literature:

1. WC Elmer, NUCLEONIC, Jan 1950 (p.26 -34)
2. H. Neat: Kernphysikalische Meßverfahren zum Nachweis für Teilchen und Quanten, Karlsruhe 1966 (p396ff)

3. P.Weinzierl, M. Drosig: Lehrbuch der Nuklearelektronik, Wien, New York 1970 (p.12 and 283)

In a counter with a dead time τ the observed count rate N_{obs} (in counts per second) is given by:

$$N_{\text{true}} = \frac{N_{\text{obs}}}{1 - N_{\text{obs}} \tau} \quad (1)$$

N_{true} is the true number of electrons/ions entering the channeltron. The dead time of the counting system (channeltron, pre-amplifier, receiver and counter card) is $\tau = 70$ ns (14 MHz), other options are 80 ns and 130 ns. The following diagram shows a calculation of formula (1) for that special case.

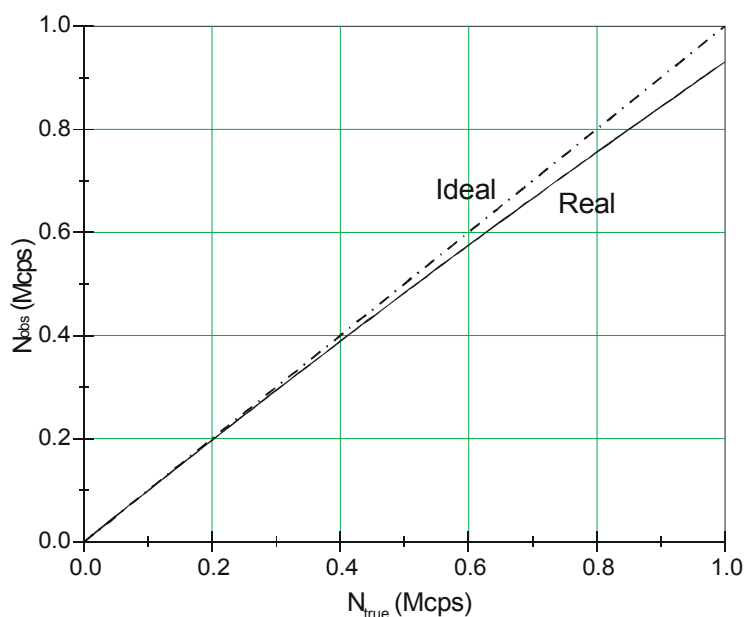


Figure 23. Observed (Real) count rates N_{obs} versus true count rates N_{true} , as calculated from equation (1). The (Ideal) straight line is shown for comparison.

Another version of the graph shown in Figure 23 for count rates up to the maximum of 14 Mcps is shown in XPS Quantitative Analysis with the Omicron EA 125, Count Rate Linearity, in the Appendix on page 77.

Figure 24 gives the difference between N_{true} and N_{obs} in % of error. It shows that, although the counter is capable of more than 10 MHz, unless the loss in observed counts is corrected for, it is wise to derive quantitative information only for count rates of up to one or two million counts per second. For an intense peak a loss in count rate around the maximum would result in relative broadening of the peak. In extreme cases ($N_{\text{obs}} > 8$ Mcps) a peak fitting routine might even suggest the distorted peak to be composed of two Gaussians.

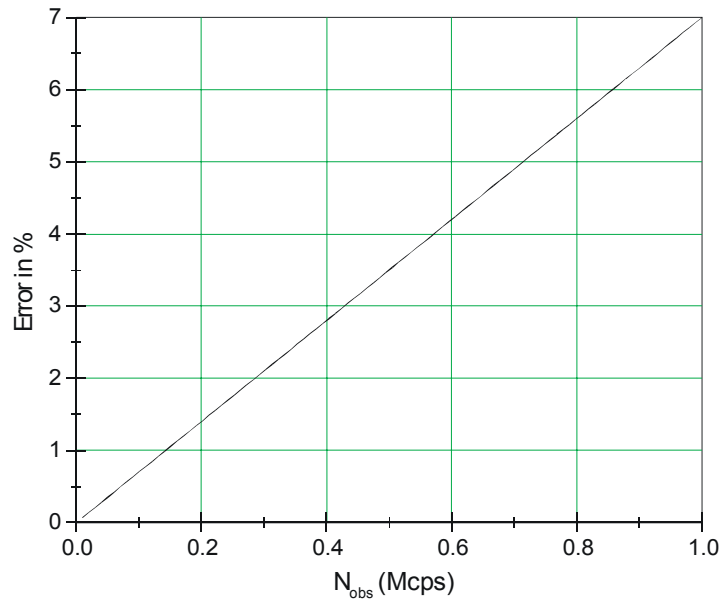


Figure 24. Difference between true count rates N_{true} and observed count rate N_{obs} against N_{obs} in % of error.

In the EA 125 multi-channel systems each channeltron measures a different part of the spectrum at any particular instant in time. These spectra are summed giving no significant loss in energy resolution and if M is the number of channels then the measured multi-channel count rate N_{obs}^M is approximately M times the count rate for a single detector. The true count rate for the multi-channel system N_{true}^M then becomes

$$N_{\text{true}}^M = N_{\text{true}} \cdot M = \frac{M N_{\text{obs}}}{1 - N_{\text{obs}} \tau}$$

where τ is the single channel dead time. This can be written in the same form as equation (1) above:

$$N_{\text{true}}^M = \frac{N_{\text{obs}}^M}{1 - N_{\text{obs}}^M \tau_M}$$

τ_M is the effective dead time for all M detectors and is related to the single channel dead time by the following equation:

$$\tau_M = \frac{\tau}{M}$$

Thus although each channel has a dead time of 70 ns, the effective dead time for 5 or 7 channels is 14 ns and 10 ns respectively.

The high count rate capabilities of the EA 125 are fully proven. Observed count rates of over 70 Mcps have been achieved.

Modes of Analyser Operation

The kinetic energy can be scanned either by varying the retardation ratio whilst holding the analyser pass energy constant (known as Constant Analyser Energy or CAE) or by varying the pass energy E_p whilst holding the retard ratio constant (known as Constant Retard Ratio or CRR). Both of these modes are selectable from the computer system.

Constant Retard Ratio (CRR) Scan Mode

In the CRR mode, electrons entering the analyser system from the sample are retarded by the lens stack by a constant proportion of their kinetic energy so that the ratio of electron kinetic energy to analyser pass energy is kept constant during a spectrum. The retard ratio k is defined as:

$$k = \frac{E_k - \phi_a}{E_p} \approx \frac{E_k}{E_p}$$

Throughout the scan range the pass energy of the analyser is continuously varied to maintain a constant retard ratio. Sensitivity and resolution are also proportional to the pass energy and therefore kinetic energy in this mode. Sensitivity is reduced at lower kinetic energies. The ESCA sensitivity for transition metals is therefore reduced when compared with that of Al or Si.

In this mode the analysed sample area and the emission angle remain almost constant throughout the whole kinetic energy range.

Constant Analyser Energy (CAE) Scan Mode

In the CAE mode of operation, the analyser pass energy is held constant, and the retarding voltage is changed thus scanning the kinetic energy of detected electrons. A range of analyser pass energies is available for selection from the control unit.

The resolution obtained in CAE is constant throughout the whole kinetic energy range.

The sensitivity, however, is inversely proportional to the kinetic energy and at lower kinetic energies is improved over that obtained with CRR. The improvement may be so great that a reduction in the X-ray power may be necessary to bring the signal within range of the detector and pulse counting system (often by up to a factor of 10). At the same X-ray power the signal intensity at the high kinetic energy end is comparable to that obtained with CRR.

In the CAE mode, the analysed sample area and the emission angle may vary slightly with the kinetic energy, but this is dependent on the type of lens design.

Selection of Analyser Mode

The CAE mode has the advantage of fixed resolution at all kinetic energies and is used in XPS over the range 150 eV to 2000 eV. Below 150 eV the CRR mode is more common in both AES and XPS. Consider now the nature of XPS and AES techniques:

- In XPS the user is frequently concerned with peaks at energies close to the photon energy (typically 1500 eV) simply because the

greatest concentration of atomic energy levels is at low binding energies.

- In AES, however, there is a tendency for peaks of interest to occur at low kinetic energies. In addition, Auger peaks tend to be broader than photoelectric peaks and high energy resolution is not as critical in AES as it is in XPS.

High resolution will provide the narrowest peaks, with reduced sensitivity. This is used to obtain accurate peak positions and derive chemical information in XPS from narrow scan spectra.

The transmission of the analyser also depends on the mode used. For further information please refer to the XPS Quantitative Analysis with the Omicron EA 125 in the Appendix on page 67 and also to Y.M.Cross, J.E.Castle: J.Electr. Spectr. Relat. Phenom **22** (1981) 53.

Analyser Resolution

The analyser is a band pass energy filter for electrons at a specific energy E_p and has a finite energy resolution ΔE which is dependent on the chosen mode of operation and specific operating conditions. The energy resolution of the analyser is given approximately by:

$$\Delta E = E_p \cdot \left(\frac{d}{2R_0} + \alpha^2 \right)$$

where d = slit width, R_0 = mean radius of hemispheres, α = half angle of electrons entering the analyser (at the entrance slit; in radian units).

The finite energy resolution of the analyser is dependent on the electron pass energy, or retardation, the slit width and the acceptance angle of the lens system. The following table lists some examples of typical parameters for various techniques and the calculated analyser resolution:

Technique	Pass energy E_p (eV)	Slit width* (mm)	Kinetic energy range E_k (eV)	Calculated analyser resolution, ΔE (eV)	Step size (eV)	Dwell time (s)
XPS Broadscan	50	6	100 – 1500	1.5	0.5	0.2
XPS Narrowscan	20	6	20	0.6	0.05	0.5
UPS Fermi edge	5	1	0.5	0.03	0.002	1
HRUPS Gas phase	0.5	1	0.1	0.003	0.0005	1

*Please note that the slit width is the effective slit widths of both the entrance and exit slits in the dispersive direction.

Table 5: Analyser operating parameters and resolution.

Peak Width Measurement

When the analyser is used to measure peak position and peak shape precisely for chemical information (as in XPS and, to some extent, in AES) the measured peak width is important and should be reduced to the lowest possible level for high resolution analysis.

The peak width (as a measure of resolution) is defined as the full width at half maximum (FWHM) of a specific peak.

Measured peak width is a convolution of several contributing line widths, assumed to be Gaussian, and is usually given as:

$$E_m^2 = E_x^2 + E_n^2 + E_a^2$$

where E_m = measured peak width, E_x = width of photon line inducing emission, E_n = width of natural energy distribution of electrons at that energy level, and E_a = finite energy resolution of the analyser.

The Natural Line Widths of Electronic Levels (E_n)

In general the natural distribution of electron energies varies from level to level, from element to element, with the excitation process, and to a lesser extent from environment to environment. Typical values can be from some meV for free atoms in the gaseous phase up to several eV for energy bands in solids. The natural line widths are usually dominated by the lifetime broadening arising from the finite lifetime of excited ionic states.

The Width of the Photon Line Inducing Emission (E_x)

The line width of the exciting photon is often the major limitation on the resolving power of the instrument. Table 6 gives widths E_x at half height for some characteristic photon lines. Typical values range from a few meV (VUV discharge lamp) to 0.85 eV (unmonochromated Al K α 1486.6 eV).

The theoretical linewidth of ultra-violet radiation from a VUV discharge lamp is limited by two processes, Doppler broadening and self-absorption. In practice, however the pressure of the discharge gas usually broadens the linewidth to between 3 and 7 meV.

An X-ray monochromator will improve the resolution by reducing the width of the exciting X-radiation to about 0.2 eV to 0.3 eV.

	Mg K$\alpha_{1,2}$	Al Kα	Al Kα (monochromated)	He I	Ne I
Energy (eV)	1253.6	1486.6	1486.7	21.2	16.7
FWHM (eV)	0.70	0.85	0.25	~0.006	~0.003

Table 6. Characteristic photon line widths.

Typical measured peak widths for XPS can be derived as shown by the following example, taking typical values of $E_x = 0.7$ eV (for Mg K α), $E_n = 0.3$ eV (for a core level electron), $E_a = 0.6$ eV (analyser energy resolution) to give E_m , the resulting measured peak width, as $E_m = 1.0$ eV.

8. Typical Experiments – Factory Tests

This section is aimed at providing an inexperienced user tips on running some typical experiments.

The experiments described are those used to test the EA 125 in the Omicron factory prior to shipment.

Standard analysers are tested for XPS and AES and high resolution (HR) analysers are also tested for HRUPS.

Analysers purchased with an EAC 2000 ISS control unit are further tested for ISS and those purchased with an X-ray monochromator are tested for monochromated XPS. For further details of these, please refer to the related manuals listed in Table 1 on page 2.

X-ray Photoelectron Spectroscopy (XPS)

The factory XPS tests consist of running a series of experiments with a Mg anode X-ray source and an Ar⁺ ion etched polycrystalline Ag sample. Various maximum intensities at given resolutions (peak FWHM) are guaranteed for the Ag 3d_{5/2} peak with an X-ray source power of 300W.

The experimental set-up is optimised for maximum sensitivity. The X-ray source is mounted perpendicular to the EA lens with the sample tilted at 45°. The X-ray source is positioned as close to the sample as possible without causing shading.

The largest entrance and exit slits are used to ensure the largest Etendue (the product of analyser analysis area and acceptance angle), as the sample is flooded with X-rays. The CAE mode is used and the pass energy is varied to achieve a range of EA resolutions. The measurements are repeated in all magnification modes.

Count rates of over 2 Mcps per channel are observed at an X-ray source power of 300W, so the power is reduced to protect the channeltrons. The high voltage is kept at 15 kV and the emission current is reduced. The measured intensity is then simply multiplied by the same ratio to give the performance at 300W. The linearity of the EA 125 performance with X-ray power has been verified experimentally. The channeltrons are also protected by starting broad survey scans at 100 eV to avoid the huge secondary electron background at low kinetic energy.

The most common problem encountered during XPS tests is low intensity. The observed intensity is strongly dependent upon the geometry of the experimental set-up and therefore only under optimum conditions, will the maximum intensity be observed.

Once the set-up has been optimised, low intensity is usually caused by a dirty sample or a poor X-ray source.

The cleanliness of the sample surface is checked by looking for the presence of the Carbon 1s and Oxygen 1s lines.

The quality of the X-ray source is checked by looking for the presence of ghost peaks. These are peaks which arise from different X-ray excitation energies from contaminants on the anode. These may include O K α , at 524.9 eV, from oxidation of the anode or Cu L α , at 929.7 eV from the substrate following degradation of the anode. In twin anode laboratory sources, cross-talk is often observed resulting in small ghost peaks corresponding to the different excitation energy. Ghost peaks can be easily identified using the EIS element library with the excitation energies of the suspected X-ray contaminants (Please see the EIS Software Manual). The presence of ghost peaks from O K α usually confirms oxidation of the anode, a condition which can also broaden the characteristic X-ray line width.

Figure 25 shows an XPS broad survey scan taken with a contaminated Mg anode X-ray source and a dirty Ag sample. All of the expected peaks are observed but also small C 1s and O 1s peaks, indicating that the sample is not clean. There are also ghost peaks due to O K α and Cu L α X-rays.

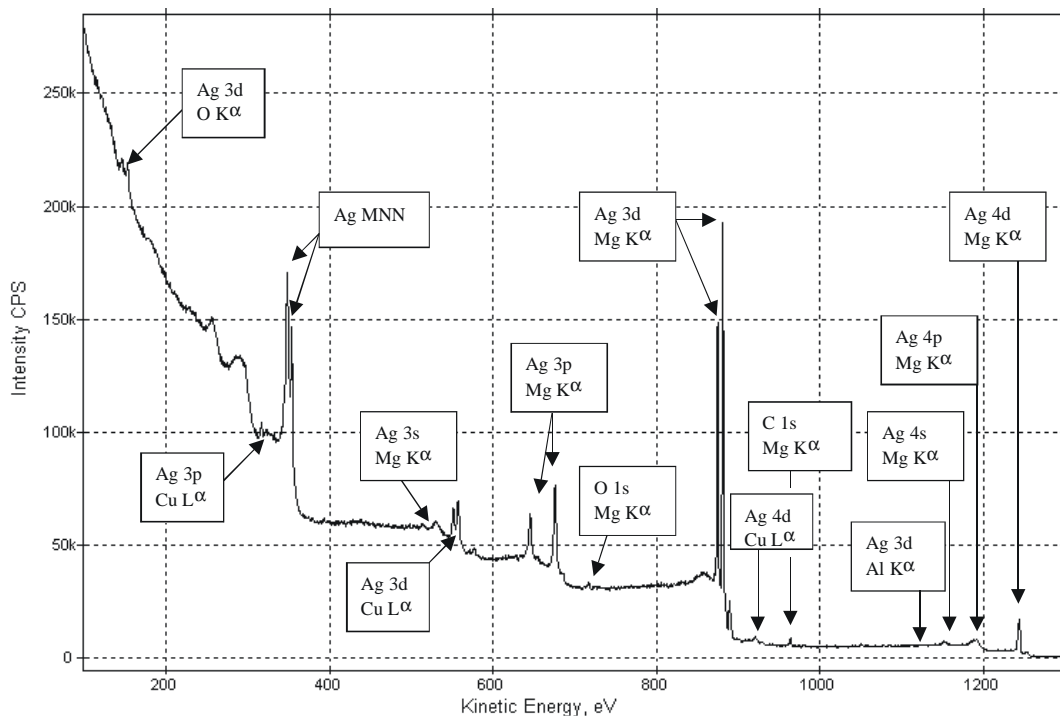


Figure 25. Analyser test, dirty XPS spectrum.

Figure 26 shows a similar spectrum taken with a new X-ray source. The absence of the C and O 1s lines indicates a cleaner sample and the absence of any ghost peaks indicates an uncontaminated anode.

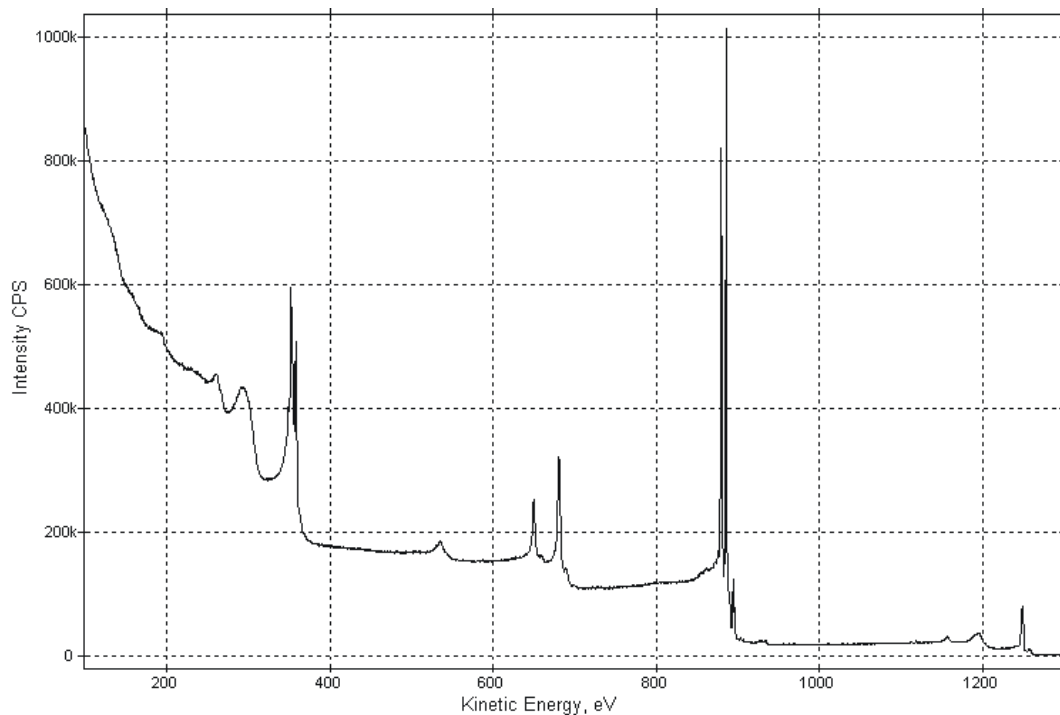


Figure 26. Analyser test, clean XPS spectrum.

The flux of X-rays emitted from the source is sometimes reduced due to a build up of sputtered material onto the Al window. Obviously, this also reduces the observed intensity

and is often very difficult to detect. Usually the only way to detect this is to examine the window and look for discolouration.

The resolution observed is usually limited by the X-ray line width and remains nearly constant for a given set of analyser parameters (Pass Energy and slit sizes). Oxidation of the anode can cause a broadening of the line width which can limit the ultimate resolution obtainable. This is detected by the presence of large ghost peaks from O $K\alpha$ X-rays.

Auger Electron Spectroscopy (AES)

The AES tests involve measuring the intensity of the Ag MNN peak per nA of beam current. As in XPS an Ar⁺ ion etched polycrystalline Ag sample is used with an electron source operating with a primary beam energy of 5 keV.

The electron source is positioned at an angle of 45° to the analyser lens and the sample is mounted with its normal in the direction of the lens.

The largest entrance and exit slits are used and the analyser is operated in CRR mode. The primary electron beam is focused into a small spot on the sample and electrons from large angles are required so the high magnification mode is used. A retard ratio of 4 is used to ensure a resolution of 0.5% (of the kinetic energy). If a retard ratio of 5 is used the analyser operates with a resolution of 0.4%. The retard ratio chosen must be large enough to ensure that the pass energy does not exceed 200 eV (the maximum pass energy of the EAC 2000) throughout the entire scan.

The measured intensity is the peak maximum minus the background measured approximately 40 eV above the peak (~390 eV). This figure is then divided by the beam current which is measured with a 20 V positive bias on the sample.

Figure 27 shows an AES spectrum of Ag.

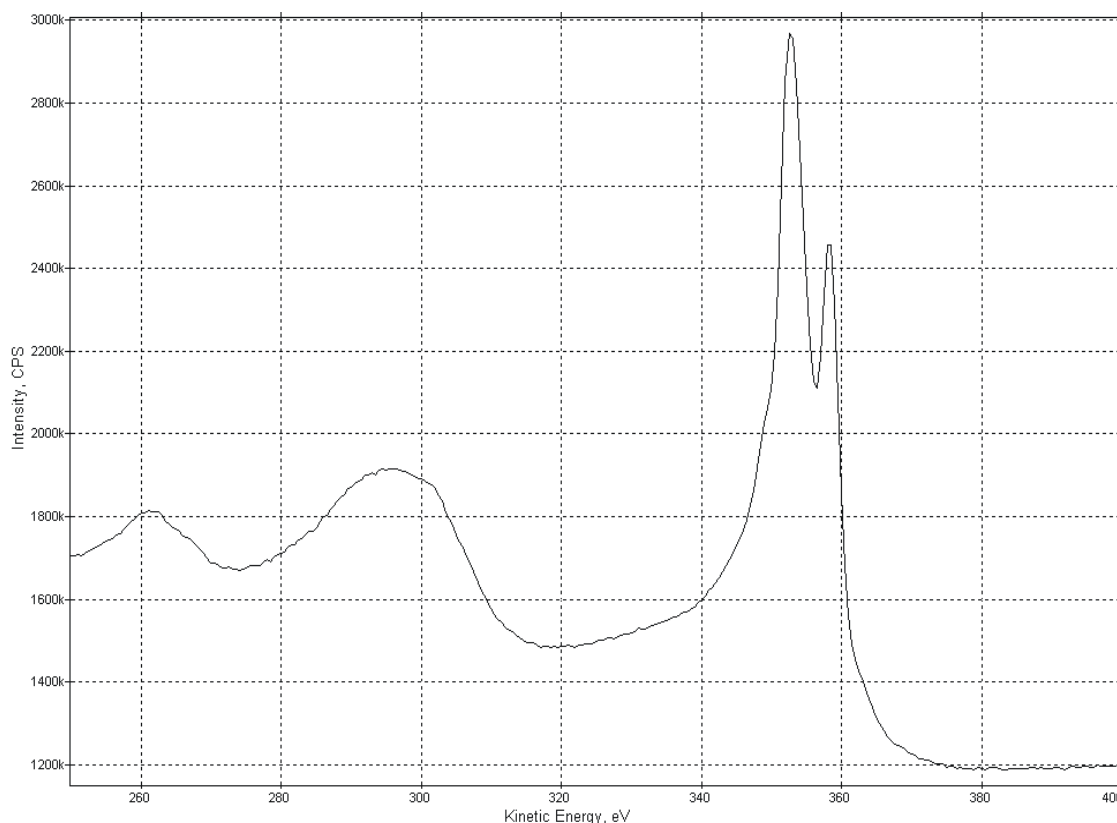


Figure 27. Analyser test AES spectrum.

As in XPS, the most common problem with the AES test is low intensity caused by a dirty sample. Again this is checked for by looking for the presence of C and O lines. The C KLL line appears at the same energy as the lower energy Ag MNV line (at ~260 eV). If this

peak appears more intense than the higher energy Ag MNV line (at ~293 eV), this is a good indication that the sample is not clean.

The other cause of low intensity is the position and focusing of the primary electron beam. This must be focused into a very small spot at the centre of the analyser analysis area to achieve the maximum performance.

The analyser resolution remains a fixed percentage of the kinetic energy, determined by the slit sizes.

High Resolution Gas Phase Ultraviolet Photoelectron Spectroscopy (HRUPS)

The gas phase UPS tests are usually only performed on HR analysers and are used to measure the ultimate resolution. The tests consist of resolution measurements of the Ne I excited Xe 5p line.

A gas cell is mounted onto the end of the light capillary of a HIS 13 VUV discharge lamp which is mounted perpendicular to the analyser lens. Apertures in the gas cell allow the photoelectrons to leave and enter the analyser lens. No extra potentials are applied to the gas cell.

It is essential that these tests are performed on a very well magnetically screened chamber as the photoelectrons have very low kinetic energies (~ 4 eV). A mu-metal chamber or stainless steel chamber with mu-metal lining is used and special care is taken to interface the mu-metal with that of the analyser lens. To achieve the best performance, the magnetic field should be less than 10 mGauss everywhere in the system.

The EAC controller used for the test depends upon the ordered configuration. The highest resolution is achieved with the dedicated EAC 300 HR with extremely low ripple and noise levels. The guaranteed resolution specification is therefore higher with an EAC 300 than with an EAC 2000.

The 1 mm slits are used and the pass energy in CAE mode is reduced to below 1 eV (usually 0.5 eV) to achieve the highest resolution. The resolution achieved is best in low magnification mode as the angles into the analyser are smaller. However due to the low acceptance angle in low magnification mode, very low count rates are observed and so the high magnification mode is more practical and is usually used.

Xe gas is leaked into the gas cell until the pressure in the chamber rises to approximately 10^{-5} mbar. This is due to the gas which has leaked through the apertures in the cell, so the pressure inside the cell is much higher. Operation of the channeltrons in this high pressure region is usually avoided, however the gas used is inert and extremely pure (99.99997 %) so does not harm the channeltrons.

The line width of the Ne radiation is reduced to a minimum by reducing the pressure of the Ne gas in the discharge lamp. This reduces the pressure broadening in the discharge. This also has the undesired effect of reducing the photon flux and hence observed intensity.

The energy position of the observed peaks is not fixed and in particular depends upon the pressure of the Xe in the gas cell. Varying this pressure changes the ionisation potential within the cell and therefore the kinetic energy of the emitted photoelectrons. This means that it is essential that the pressure is stable whilst making a measurement.

High resolution can only be achieved with extremely stable supplies. It is therefore, very important that no noise is picked up onto the supply lines. Earth loops should always be avoided by ensuring that all ground connections to the electronics and spectrometer system are common. All cables should be routed well away from sources of noise such as mains, power controllers, switch-mode power supplies or ion and plasma sources.

Figure 28 shows an MCD gas phase UPS spectrum. A typical resolution of around 4 meV is shown.

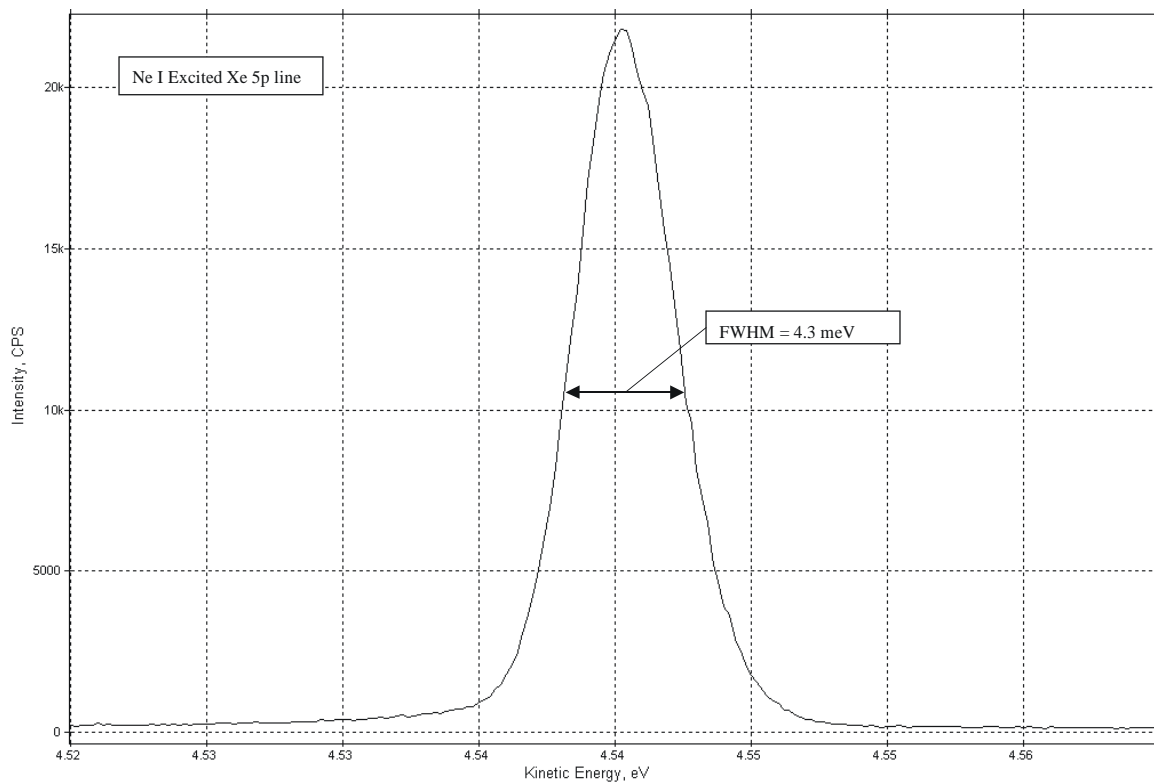


Figure 28. Analyser test HRUPS spectrum.

9. Troubleshooting

Before proceeding to attempt to troubleshoot any suspected problem with the EA 125, please ensure the following:

- All cables are connected as shown in section 5 of this manual.
- The pressure in the system is below 10^{-7} mbar.
- All electronics are switched on.
- All Green voltage supply LEDs are lit on all four electronics units.
- The nine IN TOL LEDs on the rear panel of the EAC 2000 or EAC 300 are lit.
- A suitable sample and source are present in a geometry producing electrons.

After all of the above have been checked, please read through the following titles and if any describes your problem, follow the given instructions.

Problem	Page
No Counts Observed in Software.	57
Peak Energy Changes with Pass Energy.	58
Peak Energy Changes with Time.	58
Peak Intensity Changes with Time.	59
Low Kinetic Energy Cutoff too High.	59
Poor Resolution.	59
Low Intensity.	60
Peaks at Wrong Energy.	60
Noise – Counts Observed with Channeltron HV OFF.	60
Intensity Observed from the Sample Holder.	60

If none of the above titles describes your problem, or none of the suggestions help cure the problem, please contact Omicron Service using the procedures given on page 83.

No Counts Observed in Software.



Please note: The most common cause of no counts is a cable either disconnected or connected incorrectly. Please double check all cables before proceeding.

- Using the EIS Software Instrument Control page, set a suitable KE, PE and Magnification mode.
- Click the checkbox to switch the Multipliers ON.

Check that both the red MULTIPLIER ON LEDs, one on the EAC 2000/300 and one on the Multiplier Supply, light.

Check that the LEDs on the front of the Preamp light.

Check that the Output adjust dial on the CEM Supplies is turned up to the operating value.

Check the Preamp threshold settings, see Section 6 on page 65.

Check that the entrance and exit slits are located in an indent position.

Check that the sample is in position by viewing through the high energy beam dump and lens.

Select low magnification mode (large spot) and double check the alignment of the exciting source.

Disconnect the fibre optic cable from channel 1 of the receiver. Check that red light is emitted from the fibre optic.

Firmly reconnect fibre optic. Connect a digital multimeter to the monitor cable connected to the analogue output from the receiver and check that an analogue voltage is present.

Peak Energy Changes with Pass Energy

A common problem observed when the EAC has not been finely adjusted to a specific analyser, often after maintenance of the EAC. (See EAC Adjustment on page 61 in the Appendix).

Peak Energy Changes with Time

This effect is usually caused by an insulating sample becoming charged. This can be avoided by careful use of electron and ion flood guns.

Conducting samples may also behave this way if they are not well grounded.

If the sample itself is not charging, there could be an insulator close to the sample (e.g., on the sample holder) charging and deflecting the beam.

If all of the above can be ruled out perform the following test:

- Ensure the EAC 2000/300 has been switched on for >30 minutes.
- Run 10 identical scans and note the rate at which the spectrum is shifting.
- Enter the Instrument Control page of the EIS software.
- Select and then deselect 1/10 Energy scaling.
- Switch into CRR mode and then back into CAE mode (or vice versa).
- Repeat the 10 identical scans again noting the rate at which the spectrum is shifting.

If the rate at which the spectrum shifts has dramatically increased, please contact Omicron Service using the procedures given on page 83.

Peak Intensity Changes with Time

Check that the sample or anything in the sample region is not charging as in the Peak Energy Changes with Time section above.

Check that each channeltron is on the count rate plateau (see Channeltron High Voltage Setup on page 32 and Channeltron Operating Plateau on page 41).

Check the analyser supply voltages at the filtered plug (see the EAC Electronics for EA 125 Technical Reference Manual).

If all of the above can be ruled out perform the following test:

- Ensure the EAC 2000/300 has been switched on for >30 minutes.
- Run 10 identical scans and note the rate at which the intensity is changing.
- Enter the Instrument Control page of the EIS software.
- Switch between all three magnification modes and back.
- Repeat the 10 identical scans again noting the rate at which the intensity is changing.

If the rate at which the intensity changes has dramatically increased, please contact Omicron Service using the procedures given on page 83.

Low Kinetic Energy Cutoff too High

All spectra display a low kinetic energy cutoff. When the low energy cutoff appears too high, the problem is usually caused by stray electrostatic or magnetic fields.

For applications in which low kinetic energy electrons are analysed, it is strongly recommended that mu-metal shielding is employed. It is also very important that great care is taken to interface the mu-metal of the system with that of the analyser lens.

Also check that no other instruments on the system are injecting magnetic fields into the analysis area. Any removable magnets should be taken well away from the system.

Check that the sample or anything in the sample region is not charging as in Peak Energy Changes with Time on page 58.

Poor Resolution

XPS - Check for oxidation of anode (see X-Ray Photoelectron Spectroscopy on page 50).

Check for sample surface contamination.

If the resolution requires very low temperatures, are you sure exactly how cold the sample is?

Check the analyser supply voltages at the filtered plug (see the EAC Electronics for EA 125 Technical Reference Manual).

Low Intensity

Usually caused by experimental setup, geometry, etc..

Check that the position of the sample and source are optimised for intensity.

Check that the sample surface is clean.

Check that the analyser is in the correct magnification mode.

Check that each channeltron is on the count rate plateau (see Channeltron High Voltage Setup on page 32 and Channeltron Operating Plateau on page 41).

Check the analyser supply voltages at the filtered plug (see the EAC Electronics for EA 125 Technical Reference Manual).

Peaks at Wrong Energy

Check that the sample or anything in the sample region is not charging as in Peak Energy Changes with Time on page 58.

Check that the work function has been set correctly in the EIS Software (usually ~ 4.5 eV).

Check that the peaks in question are not ghost peaks (see XPS section of Chapter 8, on page 49).

Check the analyser supply voltages at the filtered plug (see the EAC Electronics for EA 125 Technical Reference Manual).

Noise – Counts Observed with Channeltron HV OFF

Check the Preamp threshold settings see Section 6 on page 65.

Check that earth loops have been avoided by ensuring that all ground connections to the electronics and spectrometer system are common.

Check that all cables are routed well away from sources of noise such as mains, power controllers, switch-mode power supplies or ion and plasma sources.

Check that no high voltage breakdown (e.g., in an X-ray source etc.) is occurring on the system.

Check for noisy instruments on the system. Try switching each instrument off in turn.

Intensity Observed from the Sample Holder

Check that the working distance is accurately set to 30 mm.

Check that the analyser is in the correct magnification mode (High magnification for small spot).

Check that the sample is orientated correctly with respect to the lens.

Check that material from the sample holder has not been sputtered onto the sample.

Check the analyser supply voltages at the filtered plug (see the EAC Electronics for EA 125 Technical Reference Manual).

Appendix

EAC Adjustment

The aim of these instructions is to produce a constant peak position independent of the pass energy.

A constant offset throughout the whole kinetic energy range from the respective literature values is normal and can be compensated by setting the analyser work function (WorkF) to the appropriate value.



Attention. Lethal Voltages!! Adjustments and fault finding measurements as well as **installation procedures and repair work** may only be carried out by authorised personnel qualified to handle lethal voltages.

Tools required:

4. EA 125 with electronics, complete set of cables, software, PC,
5. baked UHV system with X-ray source,
6. well known sample with a feature that can be used for accurate peak positioning, e.g. silver 3d5/2 for XPS or Fermi edge for UPS,
7. **insulating** potentiometer trimmer.



Attention. Some potentiometer trimmers are anti-static and are thus conducting, **for your own safety please ensure that your Trimmer is Insulating.**

The following instructions were written for silver as an example.

It is possible, of course, to use other samples in which case only the measurement parameters have to be varied. Whichever sample is used it should be clean, conductive, grounded, and give high intensity peaks whose positions are well known.

Peak Information Tables for Silver

MgK α Excitation 1253.6 eV (with corrected Work Function)

Sample – Ag Polycrystalline foil, 99,9985%, Alfa No.944752, or Goodfellows No. Ag000465.

If AlK α excitation 1486.6 eV is used add 233 eV to all the kinetic energy (E (kin.)) values of the core level peaks. The E (kin.) and binding energy (E (bin.)) values of the Auger peaks remain unchanged.

Silver peaks:

Ag, poly	4p	4s	3d 5/2	3d 3/2	3p 3/2	3p 1/2	3s	M4VV	M5VV
E (bin.) [eV]	58	97	368	374	573	604	718	895.5	901.5
E (kin.) [eV]	1195.6	1156.6	885.6	879.6	680.6	649.6	535.6	358.1	352.1

Other Peaks:

	O1s	O KVV	C1s	C KVV
E (bin.) [eV]	531.6	745.3	284.6	990
E (kin.) [eV]	722.0	508.3	969	263.6

Table 7: Peak information for silver sample.

He (I) Excitation (with corrected Work Function)

The Fermi edge will be observed at 21.2 eV

Preparation



Please note: In the following instructions the workfunction of the analyser is assumed to have been set to 0 eV. The peak positions will, therefore, be shifted by approx. 4.5 eV to a smaller kinetic (higher binding) energy.

- Switch off the EAC 2000/300 and wait for minimum of 15 minutes until all capacitors have been discharged. **Careful! High voltages!**
- Loosen the 4 screws on the top cover and remove the cover



Attention. **Warning: Lethal Voltages!!**

The voltages present inside the EAC unit are LETHAL. Do not attempt this adjustment unless you are authorised personnel qualified to handle lethal voltages.

In particular the Focus cards in the EAC 300 require extreme care.

- Locate the potentiometer RV 1 for the EAC 2000 and RV5 for the EAC 300 on the PE outer module (see relevant part of Figure 29 on

page 64). The potentiometer can be reached through the top of the unit.

- Connect all cables of EA 125 and X-ray source/UPS Lamp.
- Switch all electronics units on and start the software.
- Allow for a warming up period of 30 min.

Adjustment procedure

1. Measure a spectrum of the Feature you have chosen in single channel mode (Select 1 channel in EIS configuration dialogue).
2. Adjust your sample for maximum intensity.
3. Measure a spectrum at the lowest pass energy and the highest pass energy you are using making sure that you are not outside the valid operating regions of the EAC (see the EAC manual for further details). Ensure that the spectra you obtain have good statistics for an accurate measurement.
4. Accurately determine the peak position with the cursor or with the Peak information window of both peaks. Make a note of the difference in Peak position and turn the potentiometer RV1 (EAC 2000) or RV5 (EAC 300) a half turn clockwise. See Figure 29 for the position of the relevant potentiometer.
5. Repeat the measurement as you did in 3 above. Again accurately determine the peak position. If the difference is less then continue with another half turn of the relevant potentiometer. Otherwise turn RV1/5 one turn anticlockwise and repeat 3 above. Continue adjusting the potentiometer until the peaks have their maximum at the same energy.
6. The accuracy with which this procedure can be performed depends upon the peak shape and width, and also the kinetic energy of the peak. An accuracy of <math><0.05\text{ eV}</math> should be attainable with the suggested XPS peak, whereas an accuracy of <math><10\text{ meV}</math> should be attainable with the UPS Fermi edge.



Please note: Four complete turns of the potentiometer are normal.

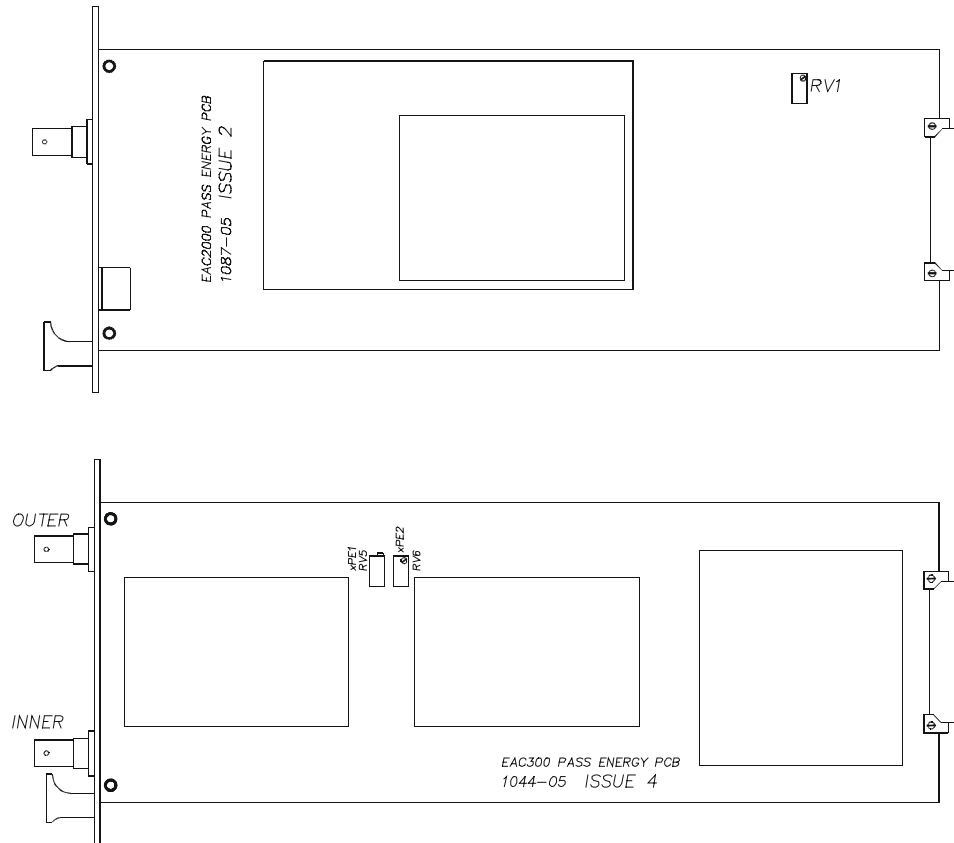


Figure 29. EAC adjustment potentiometers: Upper section, position of RV 1 on EAC 2000 outer card, lower section, position of RV 5 on the EAC 300 inner/outer cards.

After you have found equal peak energies for the pass energies, if possible check also the energy positions of some other lines in the spectrum.

For example you could measure a survey spectrum, e.g. from 100 eV to 1300 eV kinetic energy, step 0.5 eV, pass energy 70 eV.

Cross check the peak positions with reference to Table 7 on page 62, the differences should not be much larger than 1 eV. It is not worthwhile making a more accurate comparison of the peak energies as the measured values can be changed by different methods of sample preparation (chemical shifts etc.), and there are many differences in the published values of peak energies in the literature.

Preamplifier Threshold Adjustment



Please note: Read these instructions thoroughly before starting this test procedure.



Attention. Ensure that the multipliers are switched off before carrying out this procedure.

Never remove the front panel with the multiplier HV switched on. Up to 3.6 kV are present inside the unit.



Please note: Due to the sensitivity of the circuits in the preamplifier unit it is important to route all cabling to the preamplifier unit away from any sources of noise e.g. mains cables / sources of RF power.

- Make sure that all leads are connected correctly to the system and do not disconnect any lead during the test procedure.
- Start up the system as normal. Ensure that there are no counts present, i.e. switch off any X-ray sources/electron guns etc. Make sure the red multiplier LED on the front panel of the EAC 300 or the EAC 2000 is **not** lit.
- Remove the front panel on the preamplifier unit.
- Switch the mains to the multiplier unit on, again making sure the red multiplier LED on the front panel of the EAC 300 or the EAC 2000 is **not** lit.
- Set the multimeter ($\geq 10M\Omega$) to read DC MILLIVOLTS.
- **For EA 125 single channel (non-upgradable version):** connect the positive lead of the multimeter to test point 3 and the negative lead to test point 4.
- **For all upgradable EA 125 versions:** connect the positive lead of the multimeter to the red socket (test point 3) and the negative lead to the black socket (test point 4) next to the test points.
- Adjust RV1 to set the pulse threshold voltage to about 50 mV.



Please note: Do not set threshold voltages of less than 50 mV on multi-channel analysers.

- Disconnect multimeter and observe LED: it should not flash or be on continuously.
- If the LED is flashing continuously (the odd flicker is OK) then the threshold voltage is set at a level lower than the electronic noise and may have to be increased up to 50-100 mV.

If thresholds in excess of 60 mV are required then earth loop noise should be reduced by checking all ground connections to the electronics and spectrometer system are common. Also check that the cables are not routed near sources of any noise (due to radio frequencies which may emanate from badly suppressed transistor switching circuits), e.g. mains, power controllers, switch-mode power supplies, ion and plasma sources.



Attention. Operating with high threshold voltages necessitates using high multiplier voltages, a condition which can reduce Channeltron[®] operating life-time

- Repeat the above procedure for setting the threshold voltage for the remaining channels.
- Switch the mains supply off to the multiplier unit.
- Replace the front cover on the preamplifier unit.

XPS Quantitative Analysis with the Omicron EA 125

Version 1.3, 09.02.01

D. Funnemann, Omicron Vakuumphysik GmbH, Taunusstein

Full implementation of the techniques described in this paper requires the use of the 'PRESENTS' Data Presentation Package. For information about this software please contact OMICRON Sales using the telephone numbers on the front of this manual or by email to sales@omicron.de. The Phi MultiPak format is available only from EIS V2.1.

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Abstract

In this document we give a recipe to get a quantitative XPS analysis of an unknown sample using the Omicron EA 125 and the corresponding software package.

The parameters that have to be known, measured, calculated or approximated are discussed. We focus on viable solutions rather than on an exhaustive presentation.

We give numbers or equations for each parameter, so that a program can deal with them.

A procedure is given to calculate the sample composition.

Introduction

X-ray photoelectron spectroscopy (XPS) is a widely used and versatile tool to study the chemical composition within the surface region of solids. Here we give a basic introduction on how to do the first steps into quantitative XPS analysis. Here we discuss polycrystalline samples with a homogeneous depth profile. For a user who wants more accurate results we give hints for further improvement.

The first part compiles parameters and information required for the calculation. The emphasis is on making the information available in a shape that can be handled easily.

An example is given, which details the recipe on how to apply the routines within the data processing software "Presents".

Parameters

Which are the parameters to know ? - For an accurate quantitative analysis, the peak areas (intensities) and energy positions of core-level peaks are to be determined.

The measured intensity P_i of core level i is proportional to the number of atoms n_i . /Ertl, Küppers/

$$P_i = c \sigma_i \Phi \lambda T \cdot n_i$$

P_i	Peak Intensity
i	peak label
c	factor of proportionality
σ_i	cross section for photoemission for core level i
Φ	angular distribution factor
λ	effective mean free path of the electrons in the sample,
T	transmission function of the analyser, including the detection efficiency and the possible area variation with E_{kin}
n	number of atoms in the analysed volume

Relative Number of Atoms

We want to find the number of atoms n_i of a specific element. Solving for n_i yields

$$n_i = \frac{1}{c} \cdot \frac{P_i}{\sigma_i \Phi \lambda T} = \frac{1}{c} \cdot p_i$$

Relative quantification is accomplished by taking the ratio of the measured peak areas divided by the respective correction factors s :

$$n_a / n_b = (P_a / s_a) / (P_b / s_b)$$

This is the basic instruction: Find the intensity and then divide by σ_i , Φ , λ and T .

As we usually do not know c , the factor of proportionality, we can only calculate the relative number of atoms.

Let us call $p_i = \frac{P_i}{\sigma_i \Phi \lambda T}$ the corrected intensity. The corrected or reduced intensities in a spectrum are proportional to the number of atoms in the probed volume. We can scale the sum of the p_i to be 100%.

Weight Percent

When the concentration of an element is to be given in weight percent, we have to multiply the p_i with the atomic weight A_i .

How to Measure the Peak Intensity

Intensity is measured as peak area after the background is subtracted. We take the peak area, not peak intensity, as this is more independent of the pass energy chosen. Height sensitivity factors would have to specify the line width as well. An area measurement has less statistical uncertainty than the height.

Mean Free Path

Relative peak intensities can be changed dependent on the kinetic energies of the electrons. Switching the excitation energy between MgK_{α} and AlK_{α} will change the relative peak intensities, even when the cross section does not change, because the electrons travel at a different kinetic energy and are absorbed differently.

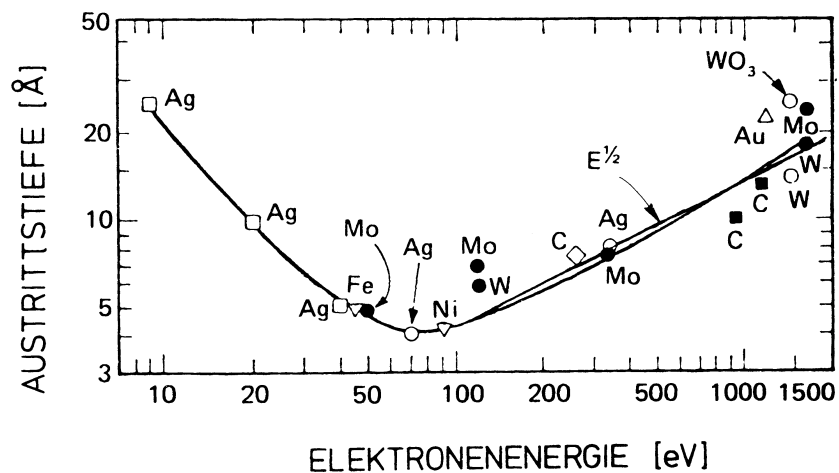


Fig. 1: Escape depth versus electron energy /Ebel ¹1985/

The diagram gives the escape depth as function of the electron kinetic energy for (mainly) metals. λ can be given in different approximations.

¹ M. F. Ebel: Röntgen-Photoelektronenspektrometrie. In: Grasserbauer, Dudek, Ebel: Angewandte Oberflächenanalyse, Springer 1985

Equation	Comment	Literature
$\lambda = A d E^{-2} + B (E d^3)^{0.5}$	Good fit to the experimental data. E is kinetic energy in eV, λ and d are measured in Ångstrom. For metals A = 538, B= 0.13. d is the interlayer distance in the sample or the atom diameter. The diagram shows clearly that for bigger atoms λ is larger than for smaller. But one has to know the interatomic distance of the material.	Dench, Seah ^{2,3} , Ebel p168
$\lambda = 0.41 d^{3/2} \sqrt{E}$	Asymptotic approximation for $E_{kin} > 150$ eV; takes into account the material used. The excitation energy sometimes can be chosen to shift the kinetic energy of the level investigated into this range.	Ertl, Küppers ⁴ p. 77
$\lambda \propto E^{0.71}$	Approximation around a kinetic energy of 1 keV. Is better approximation than \sqrt{E} , as long as no absolute values, but rather relative dependency on energy is required.	Ebel 1981, Hüfner ⁵ p. 69
tabulated	Good choice	Jablonski et al ⁶ , NIST ⁷ , Tougaard ⁸
measurement on the individual system	Best choice	Tougaard ⁹

The typical escape depth for metals is between 5 and 20 Ångstrom, for oxides between 15-40 Å and for polymers 40-100 Å. In cases only one material class (like metals) is used, it is sufficient to use the approximation $\lambda \propto E^{1/2}$. The required correction on a measured spectrum, would be to divide by $\lambda = E_{kin}^{0.71}$

When the photoelectron is looked at an angle ε from the sample normal, a correction factor has to be applied: $\lambda_{eff} = \lambda \cos \varepsilon$, if spectra taken at different angles are to be compared.

² M. P. Seah, I. S. Gilmore, S. J. Spencer, Applied Surface Science **144-145** (1999) 132

³ M. P. Seah, G. C. Smith, M. T. Anthony, Surface and Interface Analysis 15 (1990) 293

⁴ G. Ertl, J. Küppers: Low Energy Electrons and Surface Chemistry. VCH. München 1985

⁵ S. Hüfner, Photoelectron Spectroscopy, Principles and Applications, Springer 1995. Springer Series in Solid-State Sciences Vol 82.

⁶ A. Jablonski, I. S. Tilinin, J. Electron Spectrosc. Relat. Phenom. **74** (1995) 207

⁷ National Institute of Standards and Technology (NIST), USA: Electron Inelastic-Mean-Free-Path Database. (SRD71), <http://nist.gov/srd>

⁸ S. Tougaard, J. Vac. Sci A14 (1996) pp.1415

⁹ S. Tougaard. Quases.xs.REELS™, Software for Quantitative REELS, Determination of Inelastic Scattering Cross Sections, Internet: www.quases.com

Cross Section

The cross section for photoelectron excitation depends on the photon energy, the element and the specific level excited. The following diagram shows the general behaviour of the cross section versus the atomic number.

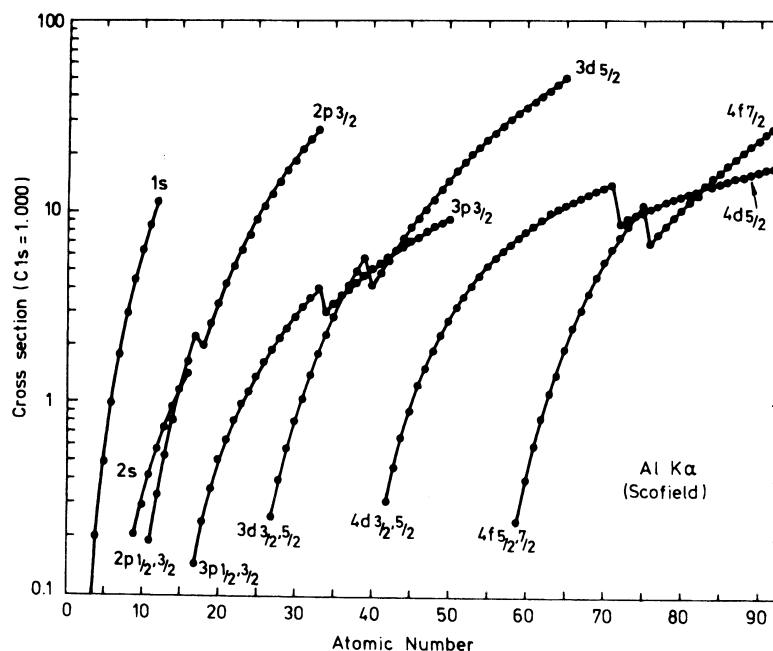


Fig. 2: Calculated cross sections /Scofield¹⁰/

/Scofield/ has calculated total cross sections σ for photoemission¹¹. The calculation is for free atoms and for AlK α (1486.6 eV) and with different cross sections for MgK α (1253.6 eV). These cross sections are used in the EIS database of the Omicron data acquisition software. Other software packages like "Spectra" and "Presents" (used by VG and by Omicron) use cross sections very similar to Scofield's. The "MultiPak" package from PHI applies different ones. - /Ebel/ gives a power series approximation for the cross sections dependent on the atomic number.

Angle Correction

The photoelectron line intensity varies with the angle Θ between the photoelectron emission direction and the X-ray beam. It is a well pronounced effect. The highest XPS intensity is found at $\theta = 90^\circ$ for most atomic levels.

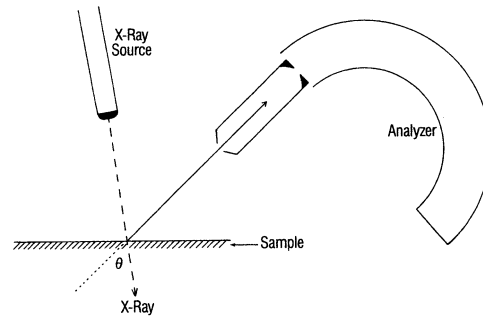
The given angular correction is applicable for polycrystalline samples, i.e. randomly oriented atoms. For XPS on single crystals (XPD) the angular distribution is different.

¹⁰ J. H. Scofield, J. Elec. Spectr. Rel. Phenom. **8** (1976) 129-137

¹¹ see also: Wagner et al: Surf Interf. Analysis **3** (1981) **211**

Definition of θ

θ is the angle between the photon direction (X-ray source) and the electron direction (lens of the analyser). This angle is given from the chamber geometry. For Omicron's Multiprobe MXPS system the angle Θ is 80° .



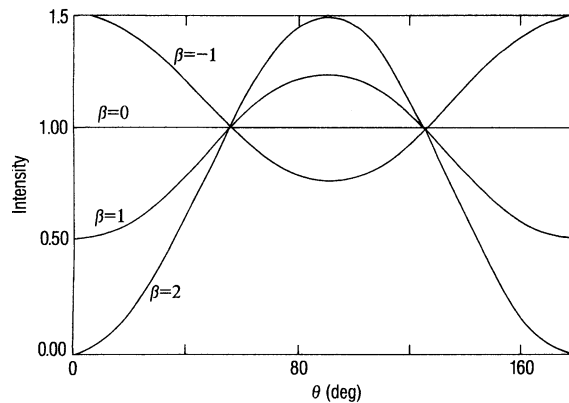
The angle between the direction of the incident x-ray and the detected photoelectron is θ .

Angular Function $\Phi(\theta)$

The angular distribution of the intensity is basically described by the differential cross section $d\sigma/d\Omega$ ¹².

$$\Phi \approx \frac{d\sigma}{d\Omega} = \frac{1}{4\pi} \cdot \left[1 - \frac{\beta}{4} (3 \cos^2 \Theta - 1) \right].$$

This formula describes the intensity variation with angle. β is the "asymmetry parameter". It depends on the angular symmetry of the atomic level excited and varies with element number Z . At the so called "magic angle" $\Theta = 54.7^\circ$ the relative intensity is $I = 1$ independent of β .



¹² J. W. Cooper, Phys. Rev. A47 (1993) 1841. Deviations from the dipole approximation are discussed in V. I. Nefedov, I.S. Nefedova: J. Electr. Spectr. Relat. Phenom. 107 (2000) 131-137

Asymmetry Parameter $\beta(\Theta)$

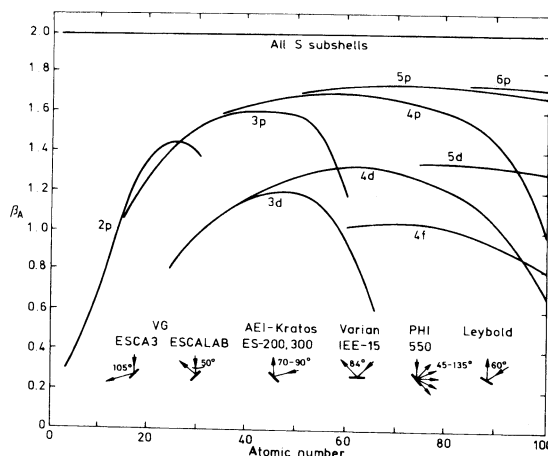
/Ebel/ gives a power series approximation with atomic number. The coefficients a, b, c are tabulated.

$$\beta = a_i + b_i Z + c_i Z^2$$

The diagram shows calculated values of the asymmetry parameter.

/Band/ et al¹³. give tabulated values for β .

The diagram shows β as a function of Z. /from Reilman¹⁴/



Analyser Transmission

The literature describes a lot of different methods for determining the transmissions function of the analyser¹⁵. Here we deal with only the simplest two of them.

First Approximation

The study of the EA 125 transmission function /Ruffieux et al¹⁶/ is based on a paper by Cross and Castle¹⁷ which is applicable to any spectrometer that can be operated both in Constant Analyser Energy (CAE) and Constant Retard Ratio (CRR) mode.

The advantage of this method is its simplicity, independence on the sample, and on the inelastic mean free path of the electrons. It can easily be used by any researcher to characterise the behaviour of his specific instrumental set-up.

To determine the required transmission function, two XPS spectra are measured, one in CRR the other in CAE mode. Their ratio R is fitted by

$$R(E_{kin}) = \frac{T(CAE)}{T(CRR)} = \frac{(PE \cdot RR)^2}{E_{kin}^{1+x}}$$

¹³ I. M. Band, Yu. I. Kharitonow, M. B. Trzhaskovskaya. At. Data Nucl. Data Tables **23** (1979) 443

¹⁴ R. F. Reilman, A. Msezane, S.T. Manson: J. Electron. Spectrosc. Relat. Phenom. **8**, 389 (1976)

¹⁵ L. T. Weng, G. Vereecke, M.J. Genet, P. Bertrand, W.E. Stone: Quantitative XPS. Part I: Experimental Determination of the Relative Analyser Transmission Function of Two Different Spectrometers- A Critical Assessment of Various Methods, Parameters Involved and Errors Introduced. Surf. Interf. Analys. **20**, 179-192 (1993)

¹⁶ P. Ruffieux, P. Schwaller, O. Gröning, L. Schlapbach, P. Gröning, Q. C. Herd, D. Funnemann, J. Westermann, Rev. Sci. Instr. **71** (10) 3634-3639

¹⁷ Y. M. Cross, J. E. Castle: J. Electr. Spectr. Relat. Phenom **22** (1981) 53

PE and RR are the pass energy and the retard ratio of the spectra involved, x is the fit parameter.

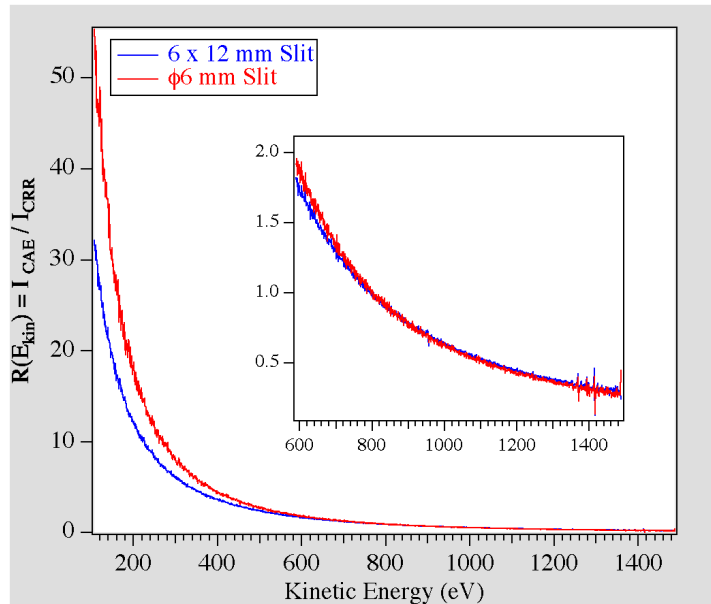


Fig. 3: The ratio between transmission in CRR and CAE mode is shown for two different slits. /Ruffieux et al./

The transmission in CRR mode $T(\text{CRR})$ is known to be proportional to E_{kin} , therefore the transmission in CAE mode is:

$$T_{\text{CAE}} \propto E_{\text{kin}}^x$$

We find that the transmission factor of the EA 125 for the CAE-mode is proportional to $E_{\text{kin}}^{-0.99}$ for most measuring set-ups. This dependence is predicted by theory for an ideal analyser, derived from the Helmholtz-Lagrange law¹⁸.

The required correction on a spectrum measured in CAE mode, would be to multiply with E_{kin} .

The energy dependent correction for the transmission function and the mean free path multiply to a correction factor of

$$\text{Corr} = \frac{E_{\text{kin}}^{0.99}}{E_{\text{kin}}^{0.71}} = E_{\text{kin}}^{0.28}$$

¹⁸ This is a general electron optical conservation law. See e.g. Cross and Castle.

Configure "PRESENTS"

This can be installed into the "PRESENTS" STARTUP.INI file.

In the section [Process] under subheading Linear we put:

[Process]

Linear=0.28

Note:

- Other values in section do not alter.
- The value should always be positive even though it will be used as a negative power .
- The item header 'Linear' is case sensitive.

Second Approximation

Deviations from the ideal behaviour occur for small retard ratios in combination with the large 6 x 12 mm² slit. However, the transmission function is predictable and smooth for any parameter range, and fits are possible using different fit functions.

The first approximation was quite good already and easy to implement. The next step is to fix the region of low retard ratio and to include variations of the transmission for different pass energies.

A general fit function can be given¹⁹ which works well for the EA 125:

$$P / E_{\text{pass}} = [a^2 / (a^2 + R^2)]^b$$

P is the peak area, RR is the retard ratio $RR = E_{\text{kin}} / E_{\text{pass}}$

¹⁹ K. Berresheim, M. Mattern-Klosson, W. Wilmers. Fresenius J. Anal. Chem. **341** (1991) 121-124

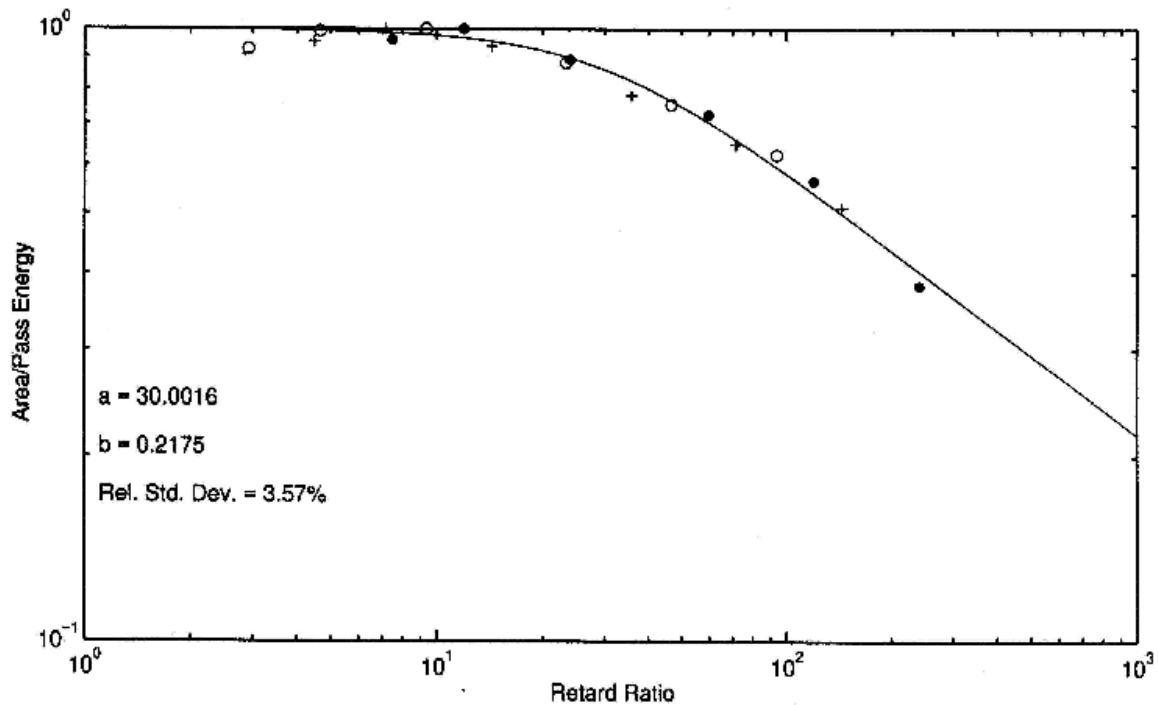


Fig. 4: Fit for the Berresheim Parameters as performed by PHI MultiPak

In general acceptable parameters for the EA 125 are: $a=6.55$ and $b= 0.45$ in high magnification mode for the largest slits.

This transmission function can be built into "PRESENTS" as well using the "VAMAS" format of the transmission function (see PRESENTS manual). When using the full VAMAS description one should include also the more accurate mean free path equation.

The accuracy will improve considerably, when the parameters a and b are determined for the current experimental setup. This facility is built into PHI MultiPak.

Possible further improvements:

This method includes a possible variation of the area the EA looks at. A set-up with a dual anode X-ray source and a monochromated X-ray source will give a different transmission function. In the former case the sample is illuminated more or less homogeneously and the EA lens cuts out the probed area. With the X-ray monochromator the probed area is rather defined from the monochromated X-ray spot. The above mentioned method allows for measurement of the transmission function quite easily. The software EIS can transfer the measured CRR and FAT data into an EXCEL™ spreadsheet. Here the ratio of the two spectra can be calculated and multiplied by E_{kin} yielding the transmission function for this set-up. It is not even necessary to find an analytic fit function. An unknown spectrum can be transferred to and corrected in the EXCEL sheet.

Checks

Before comparing the atomic composition of different samples measured within several months, the researcher should make sure that the analyser is suitable for the purpose. The measured parameters should be stable, reproducible and behave linear.

Count Rate Stability

The count rate should be stable with time. Over a period of 1h the peak area of a Cu_{2p} peak was checked to be stable within 0.5%.

Peak Position

Peak positions should not change with time or upon switching pass energy. For XPS the peak position is stable within 50 meV.

Reproducibility

Measurements should be reproducible. A measurement made on a different sample of the same element is reproducible within less than 50 meV

Count Rate Linearity

The counting system should have a linear response. The simple assumption that the detector response might be linear is not valid for modern excitation sources delivering a very high photon flux. Surprising results might appear when the detector linearity is experimentally tested /Shea, Gilmore et al/.

For a detection system with dead time τ , the relation between the observed count rate N_{obs} and the true count rate N_{true} is given by:

$$N_{obs} = \frac{N_{true}}{(N_{true} \tau + 1)}$$

The dead time for the EA 125 MCD 7 channel detection system was determined to be 10 ns, or 70 ns per channel. To put it in perspective this result says that with this counting system that is capable of counting up to 10 Mcps per channel (= deadtime 100 ns), already at a count rate of 1 Mcps, the loss in peak height is nearly 10 %.

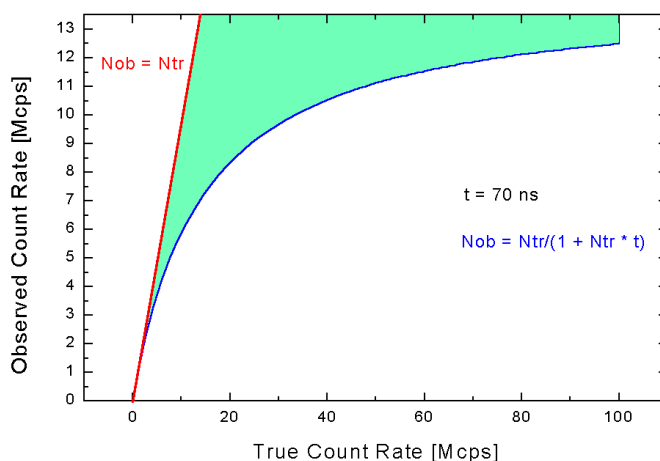


Fig. 5: Dead time counting losses

There are measures to cope with this limitation:

- Use a detector with a high maximum count rate, but do not use the limit. The peak height or area should be proportional to the X-ray intensity. A solution could be to work at an input intensity where it still is linear.

- When and as the dead time is defined and well known, the spectrum can be corrected with the above equation, before measuring the peak height or area.

- Using the peak area instead of the peak height, already reduces the error.

Example

Measurement

Start with a scan over a wide energy range, say from binding energy $E_b = -10$ eV to 1260 eV. Make sure that the number of points is not more than 4000, i.e. for this overview scan choose an energy step width of more than 0.32 eV ("Presents" can handle up to 4000 points only.) Choose the circular entrance aperture of \varnothing 6 mm. Note the angle between the EA lens and the X-ray source (When switching between a dual anode source and a monochromatic source, the angle changes).

Check that the peak intensity is not higher than about 3 Mcps per channel. In case it is, reduce the X-ray power. The pass energy chosen should be a good compromise between good count rate statistics and resolution.

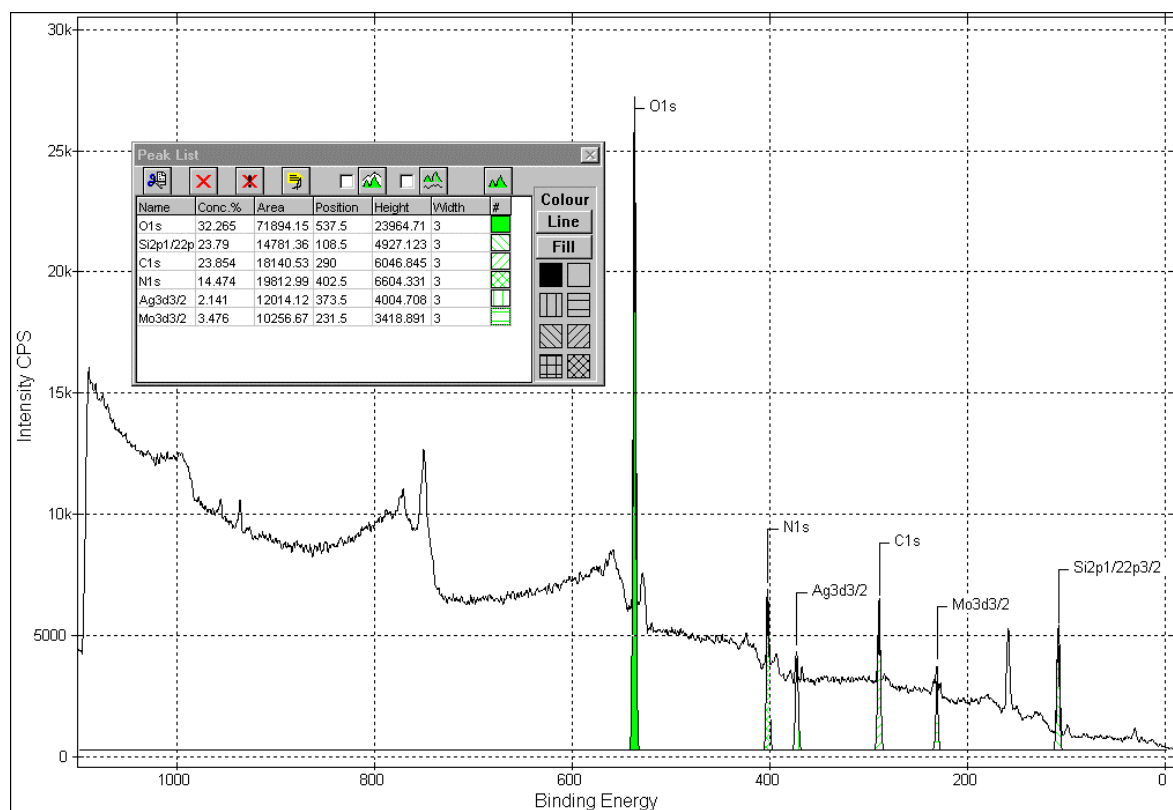


Fig. 6: Peak measurement information

Data Processing using "Presents"

1. Smooth



On the acquired spectrum we work with the tools buttons. First of all we "smooth" the spectrum with Savitzky-Golay method and choose a smooth factor of "2".

2. Corrections



Make sure the axis label is "Binding Energy"- Apply the correction " $E^{**0.28}$ ". This corrects for the mean free path, and for the transmission function.

3. Find peaks



To identify the elements present, we press the "FIND" button and choose a FWHM of 3 and a sensitivity of 2. That delivers a list of 20 peaks.

Which peak fitting and background subtraction method should be used?



There is a lot of refinement in defining the right background procedure: A linear background subtraction is the least necessary. A Shirley background helps to eliminate contributions to the data from the scattering of low-energy electrons. A Tougaard²⁰ background gives higher accuracy than Shirley. The amount of work increases from "linear" to Tougaard and the result still varies on choices you have to make about the peak shape parameters.

To keep it simple with acceptable accuracy we recommend to use the automatic peak finding routine. Only if necessary, when peaks start to overlap, the peak fitting submenu is required.

Name	Conc. %	Area	Position	Height	Width	#	Colour
O1s	100	75570	537.5	25190	3		
? 2		148920	1090	24820	6	x	
? 3		13305	108.5	4435	3	x	
? 4		16770	290	5590	3	x	

4. Identify and Select Peaks

An overview spectrum has been acquired. Identify the peaks with help of a database. For the quantification select one peak of each element or chemically shifted species.

Working through the list by pressing "?n" on the "Name" column we identify the elements (a suggestions from a database comes up for us to choose from). This selection automatically invokes a concentration display, which includes already the element specific sensitivity factor. We select just one convenient XPS peak per element. The other peaks are deleted from the list.

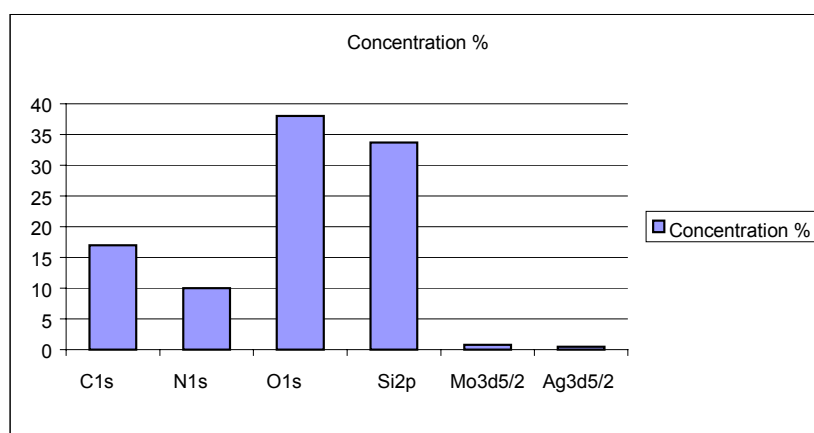
Name	Z	Position	Area	Conc 1%
------	---	----------	------	---------

²⁰ S. Tougaard: Formalism for quantitative surface analysis by electron spectroscopy. J. Vac. Sci. Technol **A8** (3) (1980) 2197.

C1s	6	290	8054	16.4
N1s	7	403	8067	9.1
O1s	8	537.5	52918	36.8
Si2p	14	108.5	14509	36.2
Mo3d5/2	42	231.5	2353	0.9
Ag3d5/2	47	373.5	3046	0.6
				100

These concentrations Conc 1% still have to be corrected using the emission angle β . After application of the correction quotient we get to C2 %, which has to be rescaled to give a sum of 100%. Note that the effect of the β correction on the final result is not a big one.

Name	β	Corr Quot.	C2%	Concentration %
C1s	0.45	1.10	14.9	17.0
N1s	0.50	1.11	8.2	10.0
O1s	0.55	1.12	32.8	38.0
Si2p	1.05	1.24	29.1	33.7
Mo3d5/2	1.18	1.27	0.7	0.8
Ag3d5/2	1.20	1.27	0.5	0.5
				100



Further Improvements

We made some "zero order" approximations or assumptions in the analysis. In general the elements present have another peak showing in the spectrum. It is a good check to use the other peak instead of the main one to cross check the elemental distribution. This check gives a good indication of the remaining error.²¹

²¹ For the accuracy possible see also: L.T.Weng et al Quantitative XPS. Part II, Surf. Interf. Analysis **20**, 193-205 (1993)

For a more detailed and sophisticated approach the reader is referred to /Ertl. Küppers²²/. Here is a list for possible further improvements for the quantitative analysis:

- Additionally to the Si2p peak at about 99.5 eV there is a Si2p shifted peak from SiO₂, which we have neglected. So we could differentiate between elemental Si and Si in SiO₂.
- Similar: There is an elemental Carbon and a shifted Carbon peak at 284 eV. We could differentiate between elemental Carbon and Carbon in a CO molecule.
- The finding of C, O and CO questions our assumption of a homogenous sample. We rather have a contamination layer on top. /Ebel. 1984²³/ gives a description of how to deal with it quantitatively.
- On a similar footing: The Si-oxide may be an overlayer. How to find out quantitatively is described in /Ebel 1985, chapter 7.1 (see Ref.1).
- The above mentioned hints give the foundation for quantitative XPS analysis. The route to becoming an expert is outlined in a paper by Castle and Baker²⁴.

Spectra and Data Compilations

National Institute of Standards and Technology (NIST), USA:

- X-ray Photoelectron Spectroscopy Database (SRD 20) <http://srdata.nist.gov/xps>

- Electron Elastic-Scattering Cross-Section Database (SRD 64)
<http://www.nist.gov/srd>

National Institute of Standards and Technology (NIST), USA: Electron Inelastic-Mean-Free-Path Database. (SRD71) <http://nist.gov/srd>

- Standard Test Data for XPS <http://www.acg.nist.gov/std>

²² G. Ertl, J. Küppers: Low Energy Electrons and Surface Chemistry. VCH. München 1985

²³ M. F. Ebel, M. F. Schmidt, M. Ebel, A. Vogel: J. Electr. Spectrosc. Relat. Phenom. **34**, 313 (1984)

²⁴ J. E. Castle, M. A. Baker: The Feasibility of an XPS Expert System demonstrated by a rule set for carbon contamination, Journal Electr. Spectr. Rel. Phenom **105** (1999) 245-256

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- [2] J. M. Walls (Editor). Methods of Surface Analysis. Cambridge University Press, UK.
- [3] H. Ibach (Editor) (1977). Topics in Current Physics **4**: Electron Spectroscopy for Surface Analysis. Springer Verlag, Berlin, Heidelberg, New York.
- [4] J. H. Moore, C. Davis and M. A. Coplan (1989). Building Scientific Apparatus. Addison-Wesley Publishing Company, Inc.
- [5] J. F. Watts (1990). Microscopy Handbooks 22: An introduction to Surface Analysis by Electron Spectroscopy. Oxford University Press, UK.
- [6] D. P. Woodruff and T. A. Delchar (1994). Modern Techniques of Surface Science. Cambridge University Press, UK.
- [7] S. Hüfner (1995). Photoelectron Spectroscopy: Principles and Applications. 2nd ed. Springer Verlag, Berlin, Heidelberg, New York.
- [8] V.S. Smentkowski: Trends in sputtering, Progress in Surface Science 64 (2000) 1-58

Service at OMICRON

Should your equipment **require service**

- Please **contact OMICRON** headquarters or your local OMICRON representative to discuss the problem. An up-to-date address list is available on our website under

<http://www.omicron.de/om-adr.html>

or via e-mail reply service under

contact.info@omicron.de

- Make sure all necessary information is supplied. Always **note the serial number(s)** of your instrument and related equipment (e.g. head, electronics, preamp...) or have it at hand when calling.

If you have to **send any equipment back to OMICRON**

- Please contact **OMICRON headquarters** before shipping any equipment.
- Place the instrument in a polythene bag.
- **Reuse the original packaging and transport locks.**
- Take out a **transport insurance policy.**

For ALL vacuum equipment:

- Include a filled-in and signed copy of the "Declaration of Decontamination" form which can be found at the back of the equipment manual.



No repair of vacuum equipment without a legally binding signed decontamination declaration !

- Wear suitable cotton or polythene gloves when handling the equipment.
- **Re-insert all transport locks** (if applicable).
- Cover the instrument with aluminium foil and/or place it in a polythene bag. Make sure no dust or packaging materials can contaminate the instrument
- Make sure the **plastic transport cylinder** (if applicable) **is clean.**
- Fix the instrument to its plastic cylinder (if applicable).

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Decontamination Declaration

If performing repair or maintenance work on instruments which have come into contact with substances detrimental to health, please observe the relevant regulations.

If returning instruments to us for repair or maintenance work, please follow the instructions below:

- **Contaminated units** (radioactively, chemically etc.) must be decontaminated in accordance with the radiation protection regulations before they are returned.
- **Units returned** for repair or maintenance must bear a clearly visible note "free from harmful substances". This note must also be provided on the delivery note and accompanying letter.
- Please use the attached attestation declaration at the end of this manual.
- **"Harmful substances"** are defined in European Community Countries as "materials and preparations in accordance with the EEC Specification dated 18 September 1979, Article 2" and in the USA as "materials in accordance with the Code of Federal Regulations (CFR) 40 Part 173.240 Definition and Preparation".

No repair will be carried out without a legally binding signed declaration !

Declaration of Decontamination of Vacuum Equipment and Components

The repair and/or service of vacuum equipment/components can only be carried out if a correctly completed declaration has been submitted. **Non-completion will result in delay.** The manufacturer reserves the right to refuse acceptance of consignments submitted for repair or maintenance work where the declaration has been omitted.

This declaration may only be completed and signed by authorised and qualified staff.

1. Description of components

Type: _____ Serial No: _____

2. Reason for return _____

3. Equipment condition

Has the equipment ever come into contact with the following (e.g. gases, liquids, evaporation products, sputtering products...)

- | | | |
|--|------------------------------|-----------------------------|
| • toxic substances? | Yes <input type="checkbox"/> | No <input type="checkbox"/> |
| • corrosive substances ? | Yes <input type="checkbox"/> | No <input type="checkbox"/> |
| • microbiological substances (incl. sample material)? | Yes <input type="checkbox"/> | No <input type="checkbox"/> |
| • radioactive substances (incl. sample material)? | Yes <input type="checkbox"/> | No <input type="checkbox"/> |
| • ionising particles/radiation (α, β, γ , neutrons, ...)? | Yes <input type="checkbox"/> | No <input type="checkbox"/> |

For all harmful substances, gases and dangerous by-products which have come into contact with the vacuum equipment/components please list the following information on (a) separate sheet(s): trade name, product name, manufacturer, chemical name and symbol, danger class, precautions associated with substance, first aid measures in the event of an accident.

Is the equipment free from potentially harmful substances? Yes No

The manufacturer reserves the right to refuse any contaminated equipment / component without written evidence that such equipment/component has been decontaminated in the prescribed manner.

4. Decontamination Procedure

Please list **all harmful substances, gases and by-products** which have come into contact with the vacuum equipment/components together with the decontamination method used.

SUBSTANCE	DECONTAMINATION METHOD

(continue on a separate sheet if necessary)

5. Legally Binding Declaration

Organisation: _____

Address: _____

Tel.: _____ Fax: _____

Name: _____ Job title: _____

I hereby declare that the information supplied on this form is complete and accurate.

Date: _____ Signature: _____ Company stamp: _____