



USER MANUAL

SCIENTA SES 100



The VG Scienta SES-100 User's Manual

1. The SES-100 Instrument Manual
2. The SES Software manual
3. Mechanical Drawings
4. Electrical Drawings
5. Appendices

SECTION 1

SES-100 Instrument Manual

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CHAPTER 1. The Instrument

The SES-100 consists of an imaging electron analyser with electron detector, HV system and a computer control and analysis package.

In this chapter each part is briefly described. Some essential features are also discussed more in detail.

1.1. The Electron Lens

The electron lens collects the electrons from the sample and transfers them to the entrance of the energy analyser. The lens has mainly three purposes.

One is to be able to physically separate the sample region from the energy analyser, thereby providing for better accessibility of the sample.

A second purpose is to act as a focusing lens, producing a photoelectron image of the sample on the entrance plane of the analyser. This makes it possible e.g. to select different analysis areas by changing the magnification. In addition, it is possible to operate the lens in a non-imaging manner, in order to utilise angular distributions etc. The third purpose of the lens is to match the initial kinetic energy of the electrons to the pass energy of the analyser. Since the analyser is operating at a fixed pass energy (see below) during the acquisition of a spectrum, the chosen energy interval has to be scanned by accelerating or retarding the photoelectrons. All lens voltages are controlled by the computer. Some lens elements are fed directly by one voltage supply referred to ground, while others are floating on top of another element. The lens electrodes, like all other surfaces seen by the electrons, are coated to provide surfaces with a very even potential distribution. The lens is optimized for high transmission or angle multiplexed recordings at different angular dispersions.

1.1.1. Details of the Lens Design

The lens consists of 7 elements, see fig. 1.1-1. The multi-element lens gives a multi-dimensional space for defining the different lens voltages. The first element is on the sample (ground) potential, and the last element is connected to the retardation/acceleration voltage. The function of the second element is to eliminate the durchgriff from the lens into the space between the sample and the lens entrance. Its potential is a constant (negative) fraction of the potential of the third element. Thus, four elements (3 – 6) are available for optimisation of the lens parameters. In the high transmission mode, one normally requires a constant image position and a constant magnification over the entire kinetic energy region. In the angular dispersive mode, the requirements are a constant position of the diffraction plane, a constant angular dispersion over the kinetic energy region, and at every kinetic energy also a constant angular dispersion of the lens/analyser system over the energy range covered by the detector. This leaves two extra degrees of freedom in the high transmission mode and one in the angular dispersive mode. The functions of the initial energy and the pass energy that define the focusing voltages are defined by a set of tables in the computer.

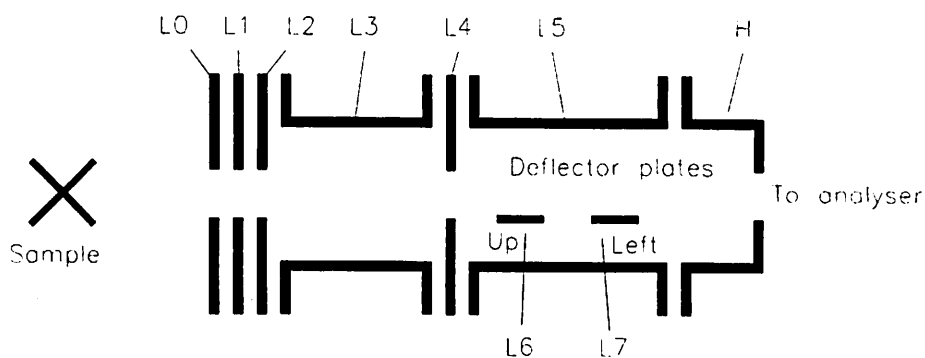


Figure 1.1-1. A schematic drawing of the electrostatic lens.

1.1.2 Lens Deflection Electrodes

Inside the sixth lens element two pairs of deflector electrodes are arranged. The deflector voltages are varied with respect to the potential of the surrounding element by 2 D/A-converters. They can be used to intentionally move the analysis spot on the sample, or to compensate for energy dependent changes in the position of the electron optical centre of the lens, caused by electric or magnetic fields. The appropriate potential differences between the electrodes in such a case will vary with the kinetic energy and the pass energy, just like the lens voltages, and they are consequently defined by functions of kinetic energy, one for each pass energy/lens mode combination. The procedure for calibrating these functions is described in Chapter 3. **Note, that by setting all these functions to zero, one obtains the same situation as in an instrument without this facility.**

1.2 The Energy Analyser

The hemispherical electron analyser is the part of the instrument that performs the actual energy dispersion. The electron trajectories are bent in the radial electrostatic field between two concentric hemispheres with a voltage difference between them. The bending radius will depend on the electron kinetic energies and an energy dispersion is achieved. The 180° hemisphere analyser has some advantages compared to other analyser types, the most prominent of which is the existence of an image plane with unit magnification perpendicular to the trajectories.

This instrument is equipped with an analyser with a mean radius of 100 mm. The separation of the hemispheres is 40 mm. Using the standard 28 mm diameter detector, the energy range that can be simultaneously recorded is about $E_{pass}/10$. The field is terminated by a plate on the centre potential of the analyser, which also serves as the mechanical base for the electrode structure. The analyser is equipped with a deflection electrode close to the entrance slit. The purpose and operating principle of this electrode is described below, see Sect. 1.2.4. All potentials are computer controlled. All surfaces exposed to the electron trajectories are coated to provide surfaces with even potential distribution. The general lay-out of the analyser is shown in fig. 1.2-1.

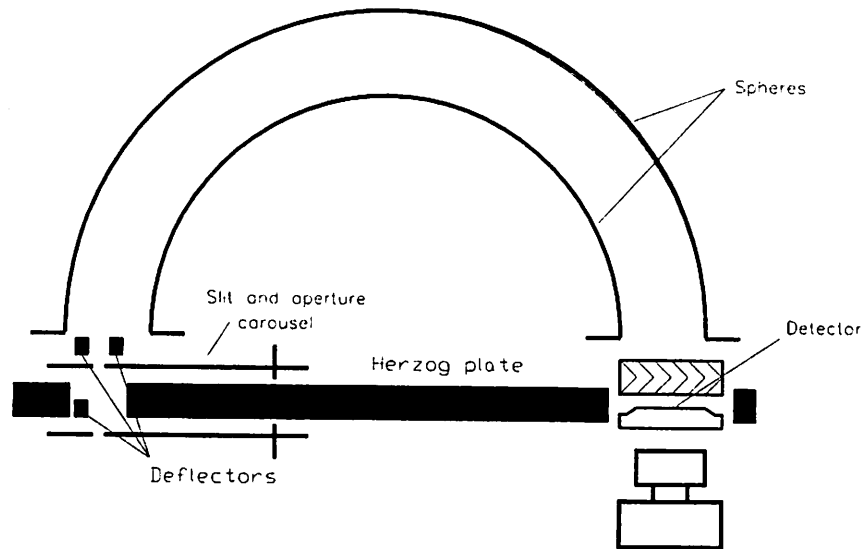


Figure 1.2-1. A schematic drawing of the analyser.

1.2.1 Slit Carousel

The minimum spatial width of the electron line focussed on the detector is defined by the width of the entrance slit and by the angular divergence in the energy dispersion direction. The energy dispersion is determined by the pass energy and the analyser radius, and the resolution is then given by the ratio of the imaged line width to the dispersion. In order to facilitate the choice of a suitable compromise between resolution and sensitivity, the SES-100 analyser is equipped with a slit carousel, providing 6 different sets of matched slit - aperture pairs. The slit carousel is operated manually through a rotational feed through. The carousel is mechanically latched to guarantee precise positioning of the slits. The slit shapes and sizes available in this instrument as well as the corresponding indices are listed in the Appendix.

1.2.2 Slit Shapes

Due to the spherical symmetry a straight slit will be imaged onto a curved line at the detector, with a radius which is half that of the analyser. Since the detector in the non-imaging mode is integrating the signals along one pixel row for each energy channel, this curvature gives a contribution to the energy broadening. For relatively wide slits (>1 mm), this effect can be neglected, but for narrower slits it becomes significant. In order to eliminate this effect, some of the entrance slits are curved with the appropriate radius to produce straight lines at the detector. A small drawback of this is that one will analyse electrons originating from a curved line on the sample.

1.2.3 Slit Deflection Electrode

The analyser has one deflection electrode sitting between the aperture slit and the entrance slit, see figure 1.2-1. This electrode is mainly intended for manufacturing tests and its voltage should be $=0$ when the instrument is working properly and the source is properly aligned.

1.2.4 Focus Adjustment Electrode

The analyser has a deflection electrode to make its focal plane coincide with the plane of the front MCP. The adjustment of this electrode is done at the factory and usually does not need any change. For very demanding cases at the lowest pass energy, a slight adjustment may be needed after baking, see section 3.4.4.

1.3 The Electron Detection System

The detector system is responsible for the detection of the electrons and also their exact position in two dimensions. This makes it possible to determine their energy and one additional parameter, either the position or angular direction (in the dimension along the slit). This chapter will briefly describe the hardware, i.e. the MCP detector, the CCD camera, and the electronics boards, and also give some information about the data transfer software.

1.3.1 Field Termination Mesh

Immediately in front of the detector a field termination mesh of 70 wires/inch is placed. Its open area ratio is about 90%. The purpose is twofold, first it ensures a homogeneous termination of the analyser field, and second it gives a possibility to put a bias voltage on the detector. A small negative bias is used to repel low-energy secondary electrons, thus substantially reducing the background. In the case of positive ion spectroscopy (ISS), a rather high negative bias is used to accelerate the ions, increasing detection probability.

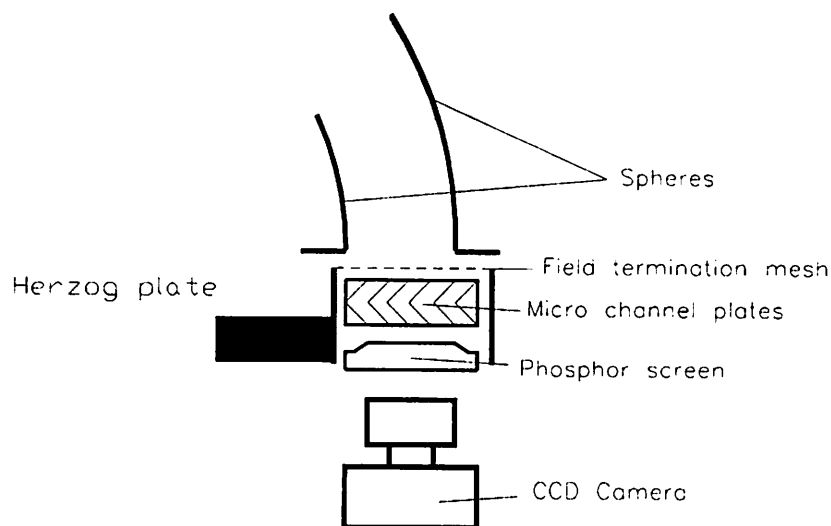


Figure 1.3-1. A schematic drawing of the detector system.

1.3.2 Micro-Channel Plates

The micro-channel plates (MCP) are probably the most sensitive piece in the entire instrument. The channel plate material is slightly hygroscopic, and therefore the detector has to be protected during transports or service, see chapter 2 and 3. The MCP's also show a slow decrease in sensitivity after prolonged use. However, if correctly handled, the MCP's will last for 5-10 years before they have to be replaced.

The detector assembly consists of two MCP plates in 'Chevron' configuration, and a fiberoptic phosphor screen. The MCP pair multiplies each incoming electron $\approx 10^6$ times and this electron pulse is accelerated to the phosphor screen, where they produce a light flash. This is subsequently detected by the CCD camera. The position of the light flash corresponds exactly to the position of the incoming electron.

The channels in the MCP's make an 8° angle against the surface normal of the plate. When the detector is mounted in the analyser, it is important that the channels of the first plate are looking

towards the outer hemisphere (c.f. fig 1.3-2) since the sensitivity of the plates is much reduced for electrons entering exactly parallel to the channels and electrons tend to imping on the detector with an direction of velocity towards the outer hemisphere.

Under normal operating conditions, the voltage over the MCP pair is 1500 - 1800 V. The acceleration voltage between the last MCP and the phosphor screen is normally 3800 V.

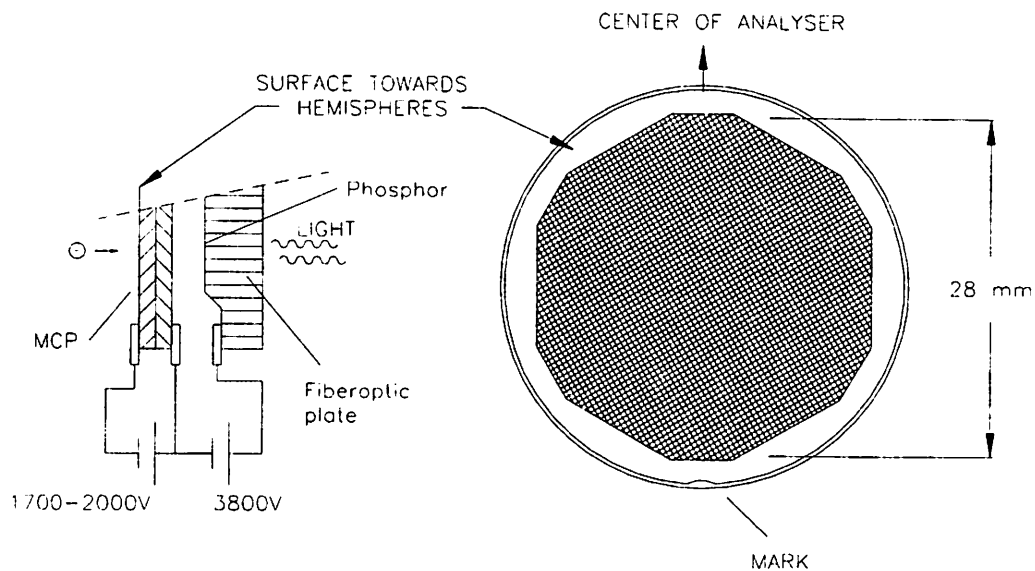


Figure 1.3-2. The MCP arrangement.

1.3.3 CCD Camera

The radial position (relative to the analyser centre) of a light flash on the detector is a function of the kinetic energy by which the corresponding electron was emitted. The CCD camera viewing the detector is mounted in such a way that the camera lines are perpendicular to the energy axis. For a given set of spectrometer voltages, the number of the camera line where a light flash is detected is a unique function of the electron energy. The area on the detector covered by the camera and the energy dispersion of the analyser determine the energy region that is covered.

The important parameters in mounting of the camera are the focusing distance, the aperture setting, and the rotation of the camera with respect to the energy axis. When the camera is removed e.g. for baking of the instrument, it should always be disconnected according to the instructions in chapter 3 in order to ensure that it will be remounted in its correct position.

NOTE: Do not change the camera aperture or focusing setting, since this will make it necessary to repeat a number of calibrations.

The video signal from the camera is connected to the detector electronics. It contains a dedicated micro-processor, which is set up for a specific experiment from the PC and is then independently acquiring data. Completed data are transferred upon request from the PC. The micro-processor

evaluates the flash positions perpendicular to the slit direction, which corresponds to the kinetic energy of the electrons. The micro-processor senses the number of pixels of which the video signal exceeds a given threshold for each line, which is proportional to the number of flashes on that line. This value is referred to as a physical channel and is stored in the counter. Because of nonlinearities in the analyser, the camera position and the energy resolution required that the physical channels are mapped into logical channels. The logical channels corresponds to the data points in a spectrum. This mapping is also performed in the micro-processor.

The data in the logical channels are accumulated during an integer number of 33 ms, corresponding to the frame rate on the CCD camera (US standard 30 Hz).

The measurements are performed in either of two modes, "fixed" or "swept". In the fixed mode the instrument is set up for a certain center kinetic energy, at the pass energy and lens mode of choice. The range of the accumulated spectrum is determined by the pass energy and the physical size of the MCP. The detector accumulates counts during the specified number of frames. The acquired data, in the logical channels, are after completion transferred to the PC.

A swept mode measurement consists of several fixed mode snapshot, where the retardation voltage is increased at increments exactly equal to the chosen energy step size in the spectrum, to move the spectrum across the detector and then add the results in the true logical channels.

To determine the mapping from the physical channels to the logical, the energy width corresponding to a physical channel must be known. This is basically determined by the analyser properties and its pass energy, but also by the camera position. A two-step procedure is used to produce the wanted mapping function: First, a linear approximation is used, the same for all pass energies, to get a mapping expressed in units of pass energy. Second, a series of measurements are taken, producing a nonlinear correction to this linear function, for each pass energy. This correction is mainly containing a third order term, and is lens mode independent. See chapter 3 for calibration instructions.

1.3.4 Data Transfer

The data transfer is using the same communication system as for the HV control. The PC sends and receives information to the fiber-optic interface board in the PC and the information is sent out on the serial link to the detector electronics. The PC is initiating a measurement and sends the requests for the original high voltages. The detector electronics sets up the acquisition routine and is then measuring on commands from the computer. The detector electronics performs all energy scale calibrations and intensity additions before it sends the results to the computer. For fixed mode scans, this means that the detector is measuring the spectrum for the whole measuring time before it sends it to the computer. During swept recordings, only those channels which are stepped over the whole detector area and will not accumulate any more counts are transferred to the computer. This reduces the amount of transferred information. It does also mean that the spectrum shown at the computer screen only contains those channels which are ready. This is the cause of the delay between the start of a swept scan and when the spectrum is appearing on the computer screen.

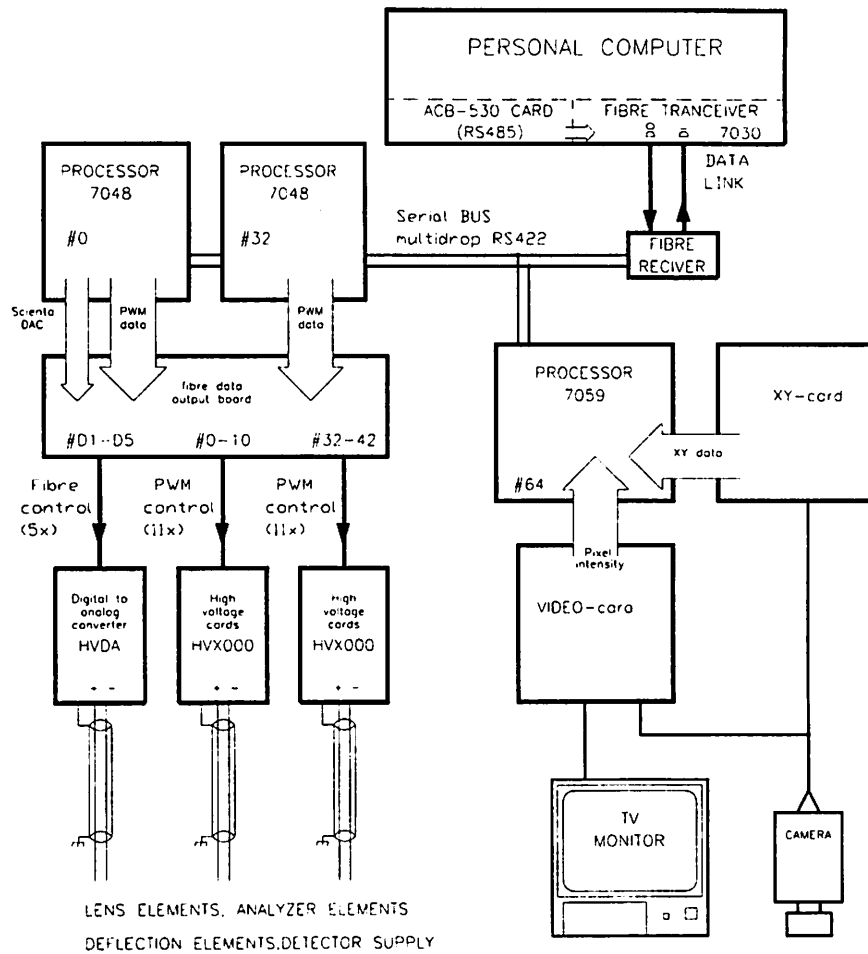


Figure 1.3-3. The data transfer system.

1.4 The High Voltage System

The GAMMADATA SCIENTA high-voltage system is designed to be used wherever high voltages at low current but high precision are needed. The system is built from modular units, which gives almost unlimited flexibility to combine different voltages. Each module is floating with respect to the ground potential up to a voltage of ± 6 kV. The voltage modules are characterised by extremely high stability and linearity, and different models ranging from 100 V to 6 kV maximum output cover the requested voltage ranges. A special D/A (HVDA) voltage module is added where a high absolute resolution of the setting is needed.

The HV modules are controlled from the PC via a control card (DO) . This is accessed through a communications system, connected to the PC via a fibre optic interface. This data link transmits all voltage settings. The communications system is very fast and allows a galvanic separated connection between the different objects at the link. The PC computer is the master in the system and contains most of the processing capability.

1.4.1 Communication

The system features a long distance, electrically isolated high speed link from the computer to the slave devices. It can be up to 10 meters long so the HV system can therefore be placed at a convenient distance from the computer. The galvanic separation prevents noise from entering the systems on both sides of the link, and also allows the whole spectrometer to be floated towards ground in special applications.

1.4.2 High Voltage Control

The high voltage control module is controlled by two slave processors. Pulse modulated light is sent through an optical fiber to each HV-card. The duty cycle is proportional to the requested voltage. The HV boards and the control cards are galvanic separated and powered from two different power supply units. The power to the control cards is controlled by the mains switch at the rear side of the HV cabinet and is possible to reset by computer but not connected to the "HV switch", see below. Each DO board controls 11 different HV boards and 4 HVDA-cards.

1.4.3 High Voltage Boards

The high voltage module settings are controlled through the fiberoptic cables. They are powered from a separate power supply unit, which is controlled by the "HV switch" at the front of the cabinet. This switch is a convenient safety/emergency switch for the high voltages. It is also interlocked by the vacuum level in the experiment chamber. Since the DO unit is not powered through this switch, the HV supplies will return to their old settings when the switch is turned on again.

The HV boards have one four-pole HV connector on the front. The lower pole is the positive voltage, the upper one is the negative one. The other two poles are not connected. The connector is normally mated to a shielded twisted pair HV cable. See figure 1.4-4. Since the supply is floating, either positive or negative voltages of the requested magnitude can be supplied. The LED at the front of the board tells if the regulation is out of limits. It may light up when a change in voltage is requested and will go out when the requested new voltage is reached in a fraction of a second. When a voltage close to zero is requested, however, the LED's may be lit for longer periods without harm. A constantly glowing LED on a board set at a non-zero voltage indicates that the board is overloaded or damaged.

WARNING: If a short circuit is suspected, always turn off the HV switch before attempting to eliminate the short or disconnecting the output cable. Removing a short with HV on may damage the supply !

All HV boards are individually tested and calibrated. The two calibration constants (a and b) which are unique for each board are noted at the inside of the front panel. These calibration constants have to be entered in the PC software, see section 1.4.6. If a HV board is replaced, the new calibration constants have to be typed in.

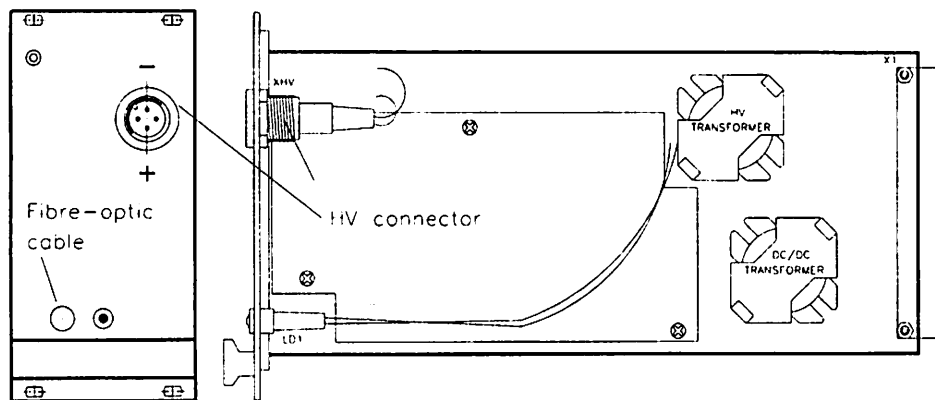


Figure 1.4-4. Schematic drawing of a HV board.

1.4.4 High Voltage D/A Boards

A special bipolar D/A (HVDA) voltage module is added where high absolute resolution ($200 \mu\text{V}$) on the settings is needed. This board responds very rapidly on voltage change requests. Its maximum voltage output range is $\pm 13.1 \text{ V}$. The address for the HVDA is set with switches directly on the board, according to figure 1.4-5.

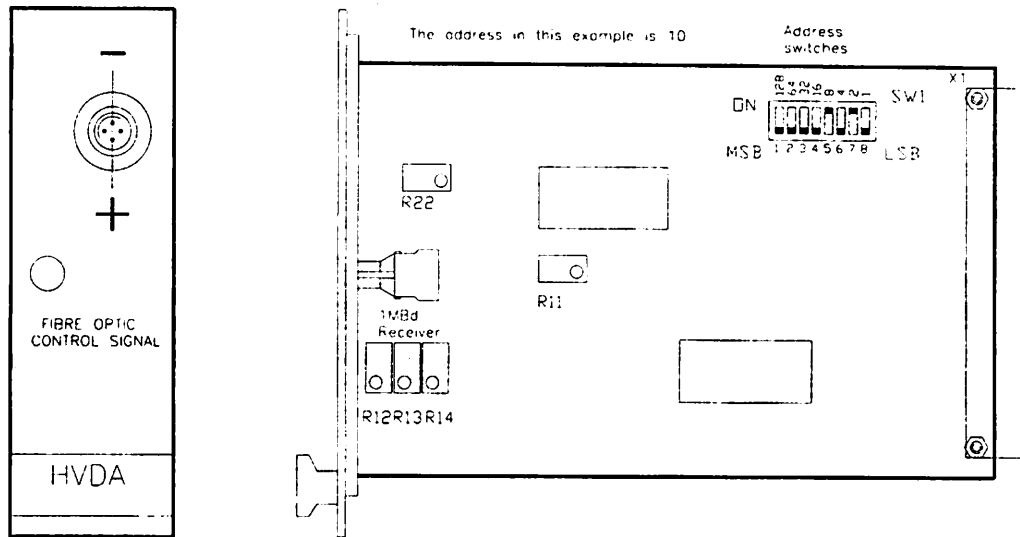


Figure 1.4-5. The HVDA board.

1.4.5 High Voltage Cables and Connection Boxes

The HV boards and HVDA boards are connected to the instrument via Shielded twisted pair HV cables. The interconnections between the different supplies providing the electrode voltages are made inside the connection boxes attached directly onto the vacuum feedthroughs.

1.4.6 Configuration

The configuration of the HV system for this analyser is visualised in diagram form. These are shown in the Appendix.

1.5 The Computer System

The advanced electron optics used in the SCIENTA SES-100 analyser depends heavily on the computer and software being able to quickly control a large number of voltages in real-time during spectrum acquisition. Much of the sophistication actually dwells in the PC software routines, and thus the instrument properties can be changed easily.

1.5.1 Computer Communications

All communication between the instrument and the computer is performed through 1 Mb/s optical fibre. This allows the whole spectrometer with electronics to be completely insulated from surrounding interference sources, and actually even floated on high potential above ground if desired.

The voltages to be requested from each supply are calculated by the PC for each energy step.

The communication with the detector system is somewhat more complicated. Here the energy calibration tables are transferred to the detector electronics together with some acquisition parameters prior to start of each region. The acquisition is started on a command from the PC, and the energy stepping (for swept mode) is also initiated by the PC. The detector electronics is collecting all data, corrects for the energy calibrations and sorts the data into logical channels. When a logical channel is finished, i.e. depending on the detector, no further information is to be added, its content is transferred to the computer.

CHAPTER 2. Running the Instrument

2.1 Alignment

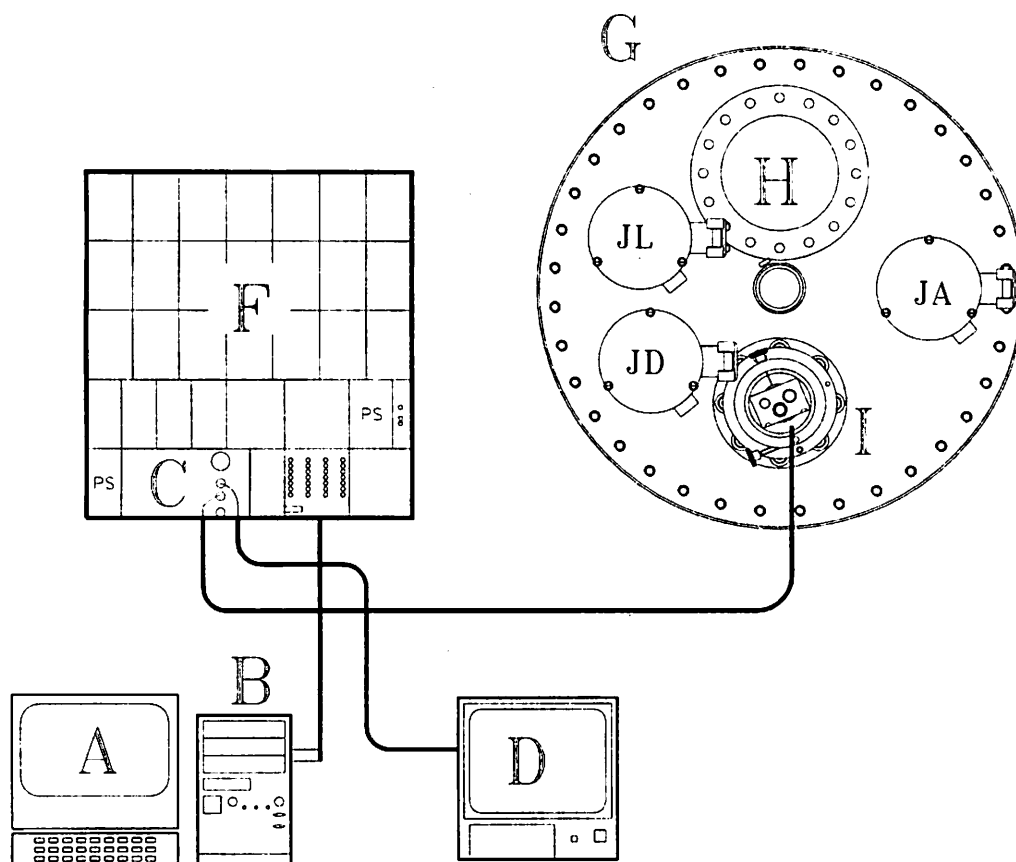


Figure 2.1-1. Schematics of the SES-100 set-up.

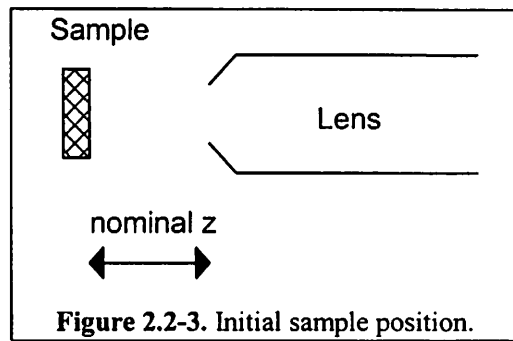
A - computer screen and keyboard, B - computer, C - ADC Detector, D - camera monitor, F - HV system, G - analyser, H - lens, I - detector and camera, JA, JL, JD - junction boxes.

2.1.1 Alignment of Excitation Source

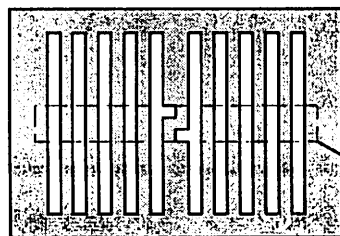
If the angle between the photon beam and the lens (z) axis is smaller than 90° , the proposed procedure is fairly straight-forward. The first thing to optimize is the z position of the lens focus. Afterwards, the x and y alignment of the sample and excitation spot should be adjusted.

2.1.2 Determination of the Electron Lens Focal Position

Put a spatially inhomogeneous sample perpendicular to the lens axis with the sample surface at the nominal lens focal distance, see figure 2.2-3 besides.



The ideal sample would be a metal plate with parallel slits with very sharp edges placed with the slits perpendicular to the analyser slit. An example is shown in figure 2.2-4. Preferably, some irregularity should be present, to be used for location of the sample. As an excitation source almost any electron creating source could be used, e.g. an electron gun, a UV source, an X-ray tube or the actual source



Analyser slit direction

Figure 2.2-4. Test sample.

itself. Use the software to choose a combination of pass energy and kinetic energy giving an intensity that can be conveniently observed on the monitor. Such an experiment setup should give rise to a striped pattern at the monitor, provided the z position of the sample is sufficiently close to the focal plane of the electron lens.

If the sample is mounted on a manipulator and is movable in the z direction, optimize the sharpness of the pattern by changing the z coordinate. Note the Δz value for later corrections of the nominal z setting.

If the sample is fixed in the z direction, this optimisation of image sharpness has to be performed by modifying the lens voltage tables instead. The procedure for this is described in chapter 3.

NOTE !

Since the modification of lens voltage tables is not trivial this procedure is not recommended unless you have a fairly thorough understanding of the electron lens. Make NO changes unless you are completely sure how to do them, and what effect they will have. If in doubt, contact SCIENTA for consultation.

2.2 Instrument Modes

The Gammadata Scienta hemispherical analyser system is very flexible regarding pass energy ranges, and alternative lens modes. In this section these parameters are described in more detail.

2.2.1 Pass Energy Ranges

The pass energy range is restricted by mainly two factors. First, the requested voltages at the lens and analyser electrodes have to be less than the maximum value of the corresponding HV board. Secondly, the step sizes of the HV boards used must not be so large compared to the electron energy used that they are manifested in the spectra. Since the HV boards setting precision is limited to 8196 steps from zero to full voltage and the pass energies may vary by a factor of 500, it is obvious that it is not possible to use only one set of HV boards for all pass energies. Therefore usually two sets are used, one for "high pass energies" and one for "low pass energies". A list of recommended HV board sets for the different pass energies is presented in the Appendix.

It is possible to run the low pass energies on the HV setup for high pass energy, but some properties such as the transmission and spatial resolution etc. might show fluctuations or small "jumps" when sweeping the kinetic energy. Furthermore, the energy resolution will be impaired, since the absolute stability of the supplies for high voltages is not sufficient at low energies.

2.2.2 Changing High/Low PE Range

- Turn off the HV switch on the front side of the HV cabinet.
- Disconnect the HV cables connected to supplies marked by H or L (High-Low).
- Connect the loose HV connectors to their new HV boards marked with the corresponding labels for the new pass energy range.
- Turn on the HV switch again.
- Check the corresponding Pass Energy range under SETUP in the 'SES' software.

2.2.3 Transmission Mode

The voltages of the different lens elements can be set in different ways, in order to optimize different properties. The most frequently requested optimisation is to maximize the total transmission through the lens. This is performed at a constant magnification of about 5X. This set of lens voltage tables is called the "transmission mode". The spatial resolution in this mode is moderate, in the order of 200 μm . This mode is intended for large-spot analysis of rather homogeneous samples.

2.2.4 Angular Dispersive Modes

By allowing the lens element voltages to vary in a different way with kinetic energy, it is possible to image the emission angle distribution at the lens exit instead of a real image. All lateral resolution is

lost, but instead is the emission angle information easily available. This way of using the lens is called "angular dispersive mode". The angular dispersion is quite high, allowing a good angular resolution. The intensity and the angular resolution will vary with the excitation spot size. For small excitation spots, the intensity in the angular dispersive mode is lower than in transmission mode, but for larger excitation spots the total transmission can be equal or even higher than in transmission mode. The nominal value of the angular dispersion is given in the Appendix. This mode is intended for photoelectron diffraction measurements and similar angle dispersive experiments.

The energy dispersion along the detector in the direction perpendicular to the slit is the same as in the other modes at the same pass energy. The energy resolution is not affected by the use of this, or any other, lens mode.

CHAPTER 3. Installation, Calibrations and Service

3.1 Mechanical Installation

3.1.1 Transport and Storage Advice

The instrument can be transported as a unit without risk of damage. For extended storage (> 2 weeks), the detector must, however, be stored in a vacuum. This can be accomplished either by pumping down the complete instrument or by dismounting the detector for separate high vacuum storage. The reason for this is, that the MCP:s are damaged due to moisture absorption.

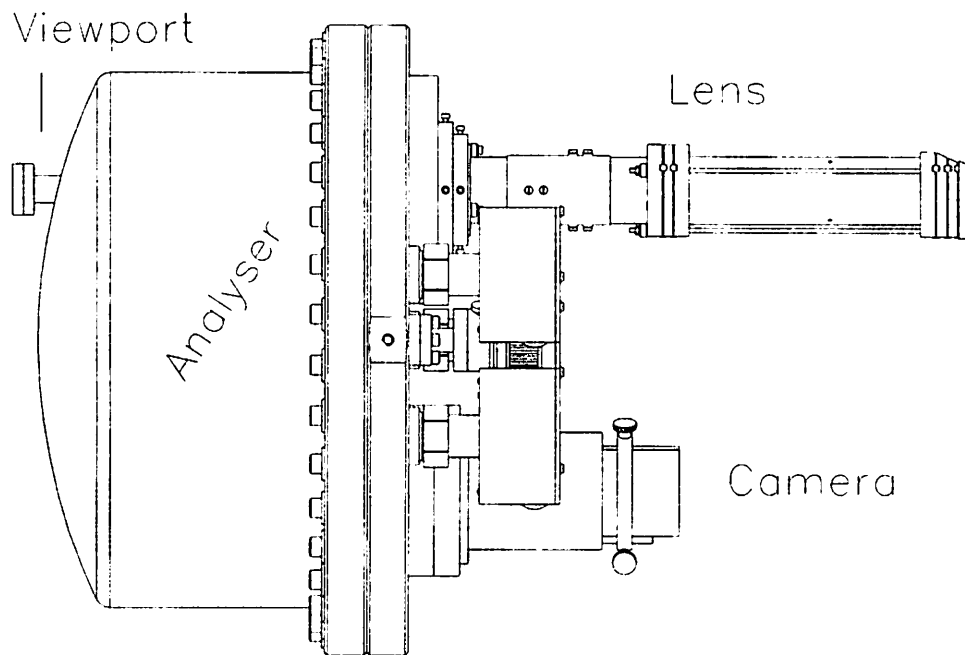


Figure 3.1-1. Gammadata Scienta SES-100 analyser.

To avoid contamination, the analyser should always be vented using dry and clean inert gas.

3.1.2 Vacuum Interlock

If the analyser is accidentally vented at operation, severe damage may result. The MCP detector will be damaged very quickly due to an intense discharge in a certain pressure region, and also the surface coating of the spectrometer electrodes will be irreversibly damaged if a discharge occurs between them. To prevent this from happening, an interlock system is provided. The connector is located in the rear of the high voltage cabinet, close to the mains switch. The male connector is delivered with a strap to make uninterlocked operation possible, and to show the correct terminals to use. Replace this strap with a 2-wire cable leading to a suitable vacuum meter (of the penning or ionisation type), provided with a relay interlock facility set at a limit not higher than $5 \cdot 10^{-5}$ mBar. The relay should close at lower pressures. Failure to use this interlock will void all warranties.

3.1.3 Magnetic Shielding

The analyser is surrounded by two layers of mu-metal to screen off external magnetic fields down to a level compatible with the very high absolute energy resolution specified. A proper shielding of the lens and the experiment chamber is also necessary, and to facilitate magnetic coupling to these parts, the SES-100 analyser is delivered with a pair of collars around the analyser end of the lens stack, having well machined end parts. GAMMADATA SCIENTA is willing to assist with consultations regarding mu-metal shielding.

3.1.4 Requirement on Experiment Chamber Equipment

The experiment chamber is usually user designed. There are, however, a few requirements and recommendations how to attach the GAMMADATA SCIENTA SES-100 analyser. The connecting flange is a NW100 CF flange, the outer surface of which is at a 400 mm distance from the optimum sample position.

3.2 Detector and Camera Installation and Service

We recommend that whenever the spectrometer is out of use and disconnected from its vacuum system, the analyser is mounted on an auxiliary turbopumped system. If this is not possible, the detector has to be dismantled and stored separately under vacuum. This section describes the procedure to be followed when the camera and detector are dismantled from the instrument in order to minimize the amount of recalibration work.

3.2.1 Mounting/Dismounting of the CCD Camera Holder

The camera with its supporting structure should be dismantled as one unit. Taking it apart into smaller pieces will invalidate some of the calibrations and it requires a substantial amount of work to restore performance. Likewise, changing any settings of the camera lens necessitates recalibrations. The camera structure is removed by taking out the two M5 screws fixing the outer camera holder to the detector flange, see figure 3.2-1.

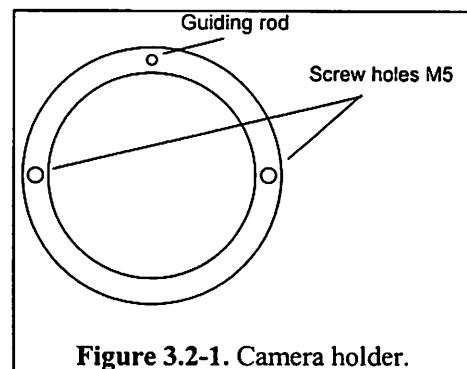


Figure 3.2-1. Camera holder.

3.2.2 Insertion/Removal of the MCP Unit

The MCP stack and the phosphor screen are mounted in an easily removable package, that is exchanged as a unit. Replacing parts inside it is difficult without special tools.

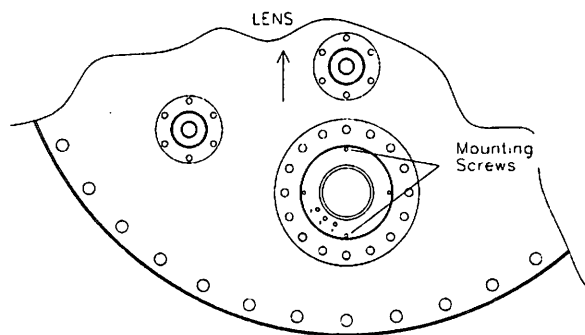
The unit is fastened to the analyser base plate with two M3 Allen screw rods. The screws used for fastening are situated along the line of symmetry passing through the lens and detector. Do not loosen the two remaining screws!! These hold the detector module together, and loosening these makes the package fall apart.

Insertion

Remove the camera viewport flange. Pull wires marked 2,3 and 4 out of way. Hold the detector package in the Allen screw rods and insert the unit in the hole in the Herzog plate. Take care not to touch the mesh situated on the front side! There are two grooves in the rim, close to one of the mounting screw rods, which shall be oriented towards the outer hemisphere. Fasten the screws until securely fastened. Put the wire connectors into the appropriate holes in the detector, according to the numbering. Make sure that they connect properly, as is indicated by increased friction in the last 4 millimeters before the bottom position. Arrange the wires not to block the sight towards the phosphor screen. Close the viewport flange.

Removal

Remove the camera viewport flange. Pull out the wires marked 2, 3 and 4. The screw rods used for fastening are situated along the line of symmetry passing through the lens and detector. Hold the package by the screw rods and pull it out. Be sure not to touch the mesh situated on the front side!



3.3 Electronics Installation and Service

This chapter contains some simple check lists and routines for connections and for testing the basic features of the electronics.

3.3.1 Connection Checklist

- Check that the fibre communication boards are mounted in the computer, c.f. figure 1.3-3.
- Connect the mains cables for the computer, screen and real-time monitor, and switch on the mains.
- Check that the switch for the HV on the front of the electronics cabinet is switched off. Connect the mains cable.
- Connect the long double fibre-optic cable between the computer and cabinet. Note, that this cable is sensitive to sharp bends, and may be broken if it is subject to careless handling.
- Connect the short fibre-optic cables from the DO board to the HV boards. They are labelled in both ends and corresponding notations are found also on the DO and HV boards, respectively.
- Connect the camera-cables. Make sure not to change the camera position relative to the holder, while connecting the cables.
- Connect the coaxial cable to the real time monitor.
- Connect the filter boxes to their respective electrical feedthroughs. Connect the cable RVL between JL and JA. Connect the cable RVD to JA and cable UF to JF. It is important that the nuts fastening the filter boxes on the feedthroughs are tightened securely to avoid excessive noise.
- Connect the HV cables to the HV cabinet. The cables are labelled in the same manner as the HV boards. Note that some cables have to be connected according to the pass energy range selected. These corresponding boards are marked 'H' and 'L' respectively.
- Connect a suitable pressure gauge interlock signal to the connector in the rear side of the HV cabinet. The spectrometer voltages are interlocked using this connector.
- Turn on the mains switch for the HV cabinet (on the rear side).

3.3.2 Disconnection Checklist

When the analyser is disconnected for transport or storage, follow the steps below:

- Check that all mains switches are turned off.
- Disconnect the vacuum interlock cable.
- Disconnect the filter boxes from the instrument.
- Dismount the camera holder, see 3.2. The analyser is now free from electrical connections.
- Disconnect the long double fibre-optic cable from the PC and the coaxial cable from the real-time monitor.

3.3.3 Electronics Service

A typical system consists of in the order of 25 different electronics cards, that are easy to change should a failure occur. Most of the units require no trimming after exchange, but the HV modules are individually calibrated and it is therefore necessary to enter a pair of calibration constants into the software when exchange of a module takes place. This is done in the following way:

- Note the ID number of the supply to be changed (#0-#10, #32-#42).
- Note its name (e.g. 'Screen') and the old calibration parameters 'A' and 'B'..
- In the SES software, select Supplies... under the Installation menu. This will lead to the Supply Setup template. Note that access to this menu is only granted 'administrator' accounts!
- Select the name from the 'Supply' list.
- Verify that the ID and the calibration parameters are correct .
- Enter the new 'A' parameter in the 'Offset' field, and the new 'B' parameter in the 'Max' field.
- Leave the Supply Setup template by clicking the 'OK' button.

Now, the new supply will produce correct output voltage.

3.4 Calibrations and Adjustments

A new instrument needs several adjustments and calibrations before successful operation can start. Some of the calibrations may have to be repeated from time to time during normal use, if maximum performance is sought. The cases when different recalibrations can be expected to be necessary are discussed separately in each section.

It is anticipated that a suitable photoelectron source is operating, and that the spectrometer works correctly so a good signal is present at the detector.

The signal size from the detector into the electronics parts depends on a number of factors. First, the voltage over the MCP's will determine the average gain through the MCP. Another variable parameter is the camera aperture. The third factor involved is the electronic discriminator level. A too low level will introduce noise, a too high level will influence the detection efficiency of low intensity signals and therefore modify the linearity of the intensity scale. Last, the black level adjustment of the CCD image processor has to be correctly adjusted.

3.4.1 CCD Camera Adjustment

Any change of the camera alignment necessitates several recalibrations. Since these procedures are quite time consuming, it is strongly recommended not to change any camera settings unnecessarily. The CCD camera is mounted in a holder, permitting rotation and translation independently. The camera lens has aperture and focus adjustment rings available.

The aperture shall be set at somewhat less than maximum, one can look into the lens and adjust the aperture until it precisely starts to be visible in the outer periphery of the lens. This adjustment is not critical.

The focal distance must be adjusted in conjunction with the translation of the camera. The optimum setting is such that the electron spots appear sharp when the detector screen periphery is precisely outside the image window, i.e. the window is fully inscribed in the screen area. The focal ring is adjusted in small steps, and the camera is moved back and forth to seek the focus distance. If the magnification is wrong, the focus ring is readjusted and so on. Finally, the translation motion is locked by tightening the screw clamping the 6 mm rod going through the separate ring around the camera holder, to prevent any translation by mistake.

The rotation must be adjusted using a sharp photoelectron line or Fermi edge. Use a pass energy of 20 eV, 0.2 mm curved slit, and rotate the camera until the highest possible resolution is achieved. Now tighten the screw clamping the rotation securely.

3.4.2 Software Detector Window

The active window can be freely defined in the software, without affecting any calibrations. There are, however, some 'hardware' dependent parameters which have better to remain unchanged. In the SES program, under the Installation menu, select the Instrument... template. Clicking 'Setup' button leads to the Detector Setup template. Under 'Usable Channels', four numbers are shown. The X-numbers must not be changed, otherwise all energy related calibrations must be repeated. The First Y and Last Y can be changed to make the active window height coincide with the analyser slit height. Such a setting may be convenient, since one can then use the maximum window as standard for the normal use.

3.4.3 MCP Voltage

A good starting approximation for the MCP voltage is 1500-1750 volts depending on MCP type. As the plate ages, a slow increase in voltage may be necessary. The voltage necessary for adequate gain is individual. There is at present no easily described way of optimising this voltage other than subjective judgement of the spot intensity as seen on the CCD camera monitor.

The channel plates are very rugged devices, and the electronics used for powering them are designed to limit the current to a safe level should accidental discharges occur. Normally, the only way MCP:s get destroyed is by moisture absorption, causing cracking of the MCP. The detector normally withstands sudden venting of the instrument, if the interlock system provided is used properly.

3.4.4 CCD Black Level and Discriminator Level

The CCD camera image processor can be operated in two different modes, 'Pulse Counting' and 'ADC' modes respectively. The differences between the two modes are implemented in the software only, electronically the unit always uses the ADC.

ADC Mode Adjustment

Turn off the high voltage switch to get zero intensity on the detector.

Always start with the ADC mode. In the SES program, select the Setup detector...template, and proceed as follows:

Energy channels: Full size.

Y Channels: Select one pixel row close to the center of the detector, e.g. 400 to 400.

Select ADC, set ADC mask to 8. Exit.

Go to the Calibrate Voltages... Template, and set the Time parameter to 1 Frame.

All other parameters may be arbitrary.

Now tune the black level knob until the count rate scale is in the order of 100.

Try to achieve a symmetric pattern with the most solid line at 60/s, and dotted lines of equal density at 30/s and 90/s. This setting of the knob is noted, and regarded as center of the '2' ADC bin.

Now repeat the procedure to achieve centering at 30/s, which corresponds to the '1' bin. Extrapolate and set the knob at the position corresponding to the center of the '0' bin.

Next, put the Y channel window to (150..600) or so, corresponding to normal height of the slit, in the Setup detector.. template. Go back to Calibrate voltages and check noise level. If the noise is not = 0, decrease the ADC Mask until it disappears (Typically Mask = 5-6). This finishes the ADC mode adjustment.

Pulse Counting Mode Adjustment

In the Setup Detector.. template, select Pulse Counting mode. Set the discriminator level to 1. In Calibrate voltages.., check the noise level with full detector window and the HV off. Increase the

discriminator level until the noise vanishes. Then increase it one step further. This finishes the Pulse counting mode adjustment.

3.4.5 Analyser Adjustments

Close to the analyser entrance, there are two adjustment electrodes. The first one is sitting between the analyser slits, and is used at the factory for trouble-shooting. The second one is used for adjustment of the focal plane of the analyser, which must coincide with the detector entrance plane.

Slit Deflection

This electrode is used to diagnose misalignment and erratic electric or magnetic fields in the analyser entrance region. Should be = 0 volts for optimal intensity.

Focal Plane

In order to produce a well focused image on the detector, the electrons have to enter the analyser at the correct angle against the effective field boundary, which due to the fringing fields lies a few degrees inside the slit and detector plane. Electrons that do not enter the analyser in the optimum direction, will hit the detector at a slightly smaller radius. The focusing is at optimum when the electron trajectories making the maximum radial angles against the center of the electron beam intersect each other in the plane of the detector. This intersection point can be shifted back and forth by changing the direction of the entire beam. To accomplish this, a voltage called 'Focus Outer Sphere' is connected to an electrode inside the hemisphere package.

In the SES program, select the Calibrate Voltages template. Use the narrowest curved slit. The calibration must be done for each individual pass energy, but is common to all lens modes. It is most convenient to use the Transmission mode to do the adjustment.

Select the pass energy to be optimised. Adjust the kinetic energy to bring a narrow structure into the detector. Select Element to be 'Focal Plane'. Then plot the width of the structure as a function of voltage, and set the Focal Plane voltage to the optimal value found.

3.5 Regular Calibrations

After the installation is completed, there are only a few calibrations which have to be repeated from time to time. These calibrations, energy resolution calibration, energy position calibration and multiple counting calibration, are described below. The normal situation is, however, that there is only need for an adjustment of the analysis spot, see next section.

3.5.1 Energy Resolution Calibration

The electrons that have passed the instrument analyser will reach a MCP and the resulting electron shower hits a phosphor screen where light flashes are generated. The flashes are detected by a CCD camera, with the lines perpendicular to the energy direction of the detector. This means that each camera line represents a unique kinetic energy. The energy separation between each pair of lines is slightly non-linear, so to optimise the resolution a correction table, individual for each instrument, can be produced.

Method

A number (N) of swept mode measurements of a spectrum containing one well-defined peak are performed, each using $1/N$ of the detector energy width as the active part. The detector window is moved along the energy axis between the recordings, in order to give N spectra, collected at successive parts of the detector. The apparent position of the peak will in general differ slightly between the acquired spectra, and the differences in peak positions are used for correcting the non-linearity of the energy separations. In theory the best calibration should be achieved if one spectrum was recorded for each camera channel, but in practice this requires too much recording time. In practice "Spline" approximations are used between a number (typically 10 - 20) of measured points. In the present software, N is set to 19.

This resolution calibration has to be done for each pass energy. It has to be performed every time the camera and/or detector positions relative to the chamber has been changed. Even if the detector is not moved, these calibrations should be performed every 24 months just in case any detector details might have changed their properties somewhat. This calibration destroys the "energy position calibration". However, the calibration is valid for all different kinetic energies and is not necessary to recalibrate when changing excitation source.

General Instructions

The calibration runs must be performed with a photo-electron line which is narrow enough to determine the peak position with sufficient accuracy. For the XPS energy range, you would typically require that the contribution to the resolution from the non-linear dispersion should not exceed 0.01 eV, and this means that it should be possible to determine the peak position with this accuracy. When calibrating for UPS or synchrotron radiation use, where mV resolution is required, the test line should be narrow enough to give the peak position to a fraction of meV. For XPS calibrations we normally recommend the narrow Au 4f or Ag 3d lines. For UPS, the ideal sample is a noble gas or the Fermi edge of a cold sample. Select the narrowest curved slit in order to have a good peak position determination.

For details about the calibration procedures, please refer to the software manual.

3.5.2 Energy Position Calibration

Simplified, the absolute electron kinetic energy will depend on the excitation energy minus the binding energy of the electron. For a more accurate determination, the work function differences in the instrument must be taken into account, and probably there are some minor effects as well, which shift the absolute value of the kinetic energy. For instance, the nominal pass energy of the analyser may not correspond exactly to the center of the detector. The easiest way to compensate for this is to position calibrate the energy scale experimentally. The position can be changed by potential differences, e.g. during charge neutralisations etc., and this calibration can be used to compensate also for such effects.

All calibrations and run parameters are described in the software manual.

3.5.3 Multiple Counting Calibration

The absolute intensity scale is often difficult to determine. In the present detector system, one light spot at the detector is normally covering more than one camera pixel, and the original electron is counted as several electrons. In the ADC mode, the average output from each pixel corresponding to a single electron results in a number of the order of 10. To get a valid intensity measure, a multiple counting factor (MCF) is introduced. This is simply a constant which corresponds to the average total output per incoming electron.

Method

The calibration method for the MCF is based on the true statistical noise in a spectrum. The statistics of the detection process is approximated with a Poisson statistics. The standard deviation of a Poisson distribution equals the square root of the average absolute value. In the present system, this Poisson distribution is convoluted by the gain distribution of the MCP and the camera. The standard deviation is, however, not altered significantly, so it is still equal to the square root of the average value of the actual number of electrons. That means, that even if the absolute number is multiplied by a certain factor, the deviation is still characteristic for the original intensity.

If the user finds some other method to calculate this factor, it can also be entered manually.

3.6 Bake-Out

The analyser can be operated safely once the pressure is lower than $5 \cdot 10^{-5}$ mBar. This limit is mainly imposed by the detector, but also electron scattering in the analyser starts to be observable above this pressure. Many applications, however, require an atomically clean surface and the pressure during analysis has consequently to be in the range below 10^{-9} mBar. To achieve such vacuum levels in a reasonable time, the equipment has to be baked-out.

3.6.1 Dismounting Before Bake-Out

The SES-100 analyser is bakeable to 150°C. There are, however, a few details which have to be dismantled before baking.

Remove the filter boxes by unscrewing the entire box from the feedthrough using the supplied key. Check the labelling of the boxes and corresponding feedthroughs.

Remove the CCD camera unit, see 3.2.

3.6.2 Advice for Bake-Out

The following recommended procedures only pertains to the Gammadata Scienta equipment.

WARNING !

The user must check that the recommended procedures are compatible with other equipment attached to the same vacuum system. Gammadata Scienta takes no responsibility for any damage caused by baking additional equipment which was not delivered by Gammadata Scienta.

To protect windows and feedthroughs from fast temperature changes, we recommend that they are wrapped with aluminium foil.

The recommended maximum bakeout temperature is 150°C. Baking to higher temperatures is performed completely at the users own risk. Limiting materials are polyimide and Teflon. During the first bakeout after delivery, the equipment may have to be kept at maximum temperature for up to a week due to outgassing of graphite coated surfaces and polyimide insulators. Subsequent bakeouts after short ventings with dry inert gas are usually completed in 24 hours.

3.6.3 Re-Mounting After Bake-Out

Connect the HV connection boxes by fastening them firmly directly onto the feedthrough. Check that the boxes and feedthrough flanges are correctly labelled.

Remount the CCD camera unit. Follow the instructions of chapter 3.2.