Calibration of the axaf-hrc UV/Ion shields at Osservatorio Astronomico di Palermo G.S. Vaiana: I - Instrumental set-up

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ABSTRACT

We describe the equipment and the experimental set-up at the XACT facility - Osservatorio Astronomico di Palermo G. S. Vaiana, employed in the calibration of the AXAF-HRC UV/ion shield. The facility has been expanded to improve its performance and to extend its bandpass to UV wavelengths. It now covers the 2550 - 1 Å wavelength range, is equipped with an advanced micropositioning system, has imaging capabilities in the wavelength range 1200-1 Å. The test chamber now opens to a class 1000 clean room which, along with the oil-free pumping system, makes cleanliness one of the characteristics of the facility.

1 INTRODUCTION

The X-ray Astronomy Calibration and Testing Facility (XACT), in its basic configuration, was already described in a previous paper.[?] To meet the requirements of the calibration of the AXAF-HRC UV/Ion shields,[?,?] the basic equipment has been expanded. In particular, the addition of a UV beam line including a grazing incidence monochromator, of a X-ray transmission grating and of a micro-channel plate based XUV - X-ray detector (MCP) have improved the precision achievable in transmission measurements extending at the same time sensitivity to UV wavelengths. The installation of a class 1000 clean room enclosing the test chamber allows manipulation of samples in a dust-free environment.

The facility is presently being employed for the calibration of the UV/ion shields of the High Resolution Camera of the Advanced X-ray Astrophysics Facility (AXAF-HRC) and for part of the filter set of the European Photon Imaging Camera of the X-ray Multi Mirror Mission (XMM-EPIC).

In this paper we briefly summarize the basic configuration of the facility, concentrating on the new equipment installed for the calibration of the AXAF-HRC UV/ion shields, and on the experimental setup adopted in the measurements.

The results of calibration will be presented elsewhere.[?,?,?] Here we just mention that calibration is still in progress, since measurements conducted on the baseline design UV/Ion shield showed an unexpectedly high transmission at wavelengths longer than 2300 Å which led to a redesign of the shield itself and to a delay in the calibration program.

2 INSTRUMENTATION

2.1 Basic instrumentation

In this section we give a brief description of the instrumentation previously described[?] i.e. the equipment available when the facility started operating. It includes: a stainless steel (AISI 304 L) vacuum chamber, a set of cryopumps to produce and maintain the vacuum in the chamber, a multi-anode electron impact X-ray source, gas detectors, support electronics for data acquisition and control.

2.1.1 The Vacuum Chamber

The vacuum chamber, shown in Fig. ??, includes a 16 meter pipe connecting the X-ray source (Fig. ??) to the test section, and the test section itself, shown in Fig. ?? in its basic configuration. The diameter of the pipe increases from the source end to the test section end, following the divergence of the beam, from a minimum of 150 mm to a maximum of 630 mm.

The test section is a 1000 mm diameter, 1000 mm long stainless steel cylinder with several ports for inspection, instruments and feedtroughs, and a door in the back having the same diameter of the chamber and opening to a class 1000 clean room. The test section can be isolated from the pipe by means of a sliding gate valve with the same diameter of the pipe (630 mm). Normal operation pressure is in the range $5 \times 10^{-7} - 2 \times 10^{-6}$ $mbar$.

2.1.2 The Vacuum System

The vacuum system is based on cryogenic pumps for the chamber and on a magnetic levitation turbo molecular pump for the X-ray source.

The cryogenic pumps (Edwards Coolstar series), have a total nominal pumping speed of 3900 l/s; 2400 l/s are allocated to the pipe, distributed over 4 units, and 1500 l/s are allocated to the test section. The redundancy of the pumping system allows operation under failure of up to two cryopumps. Pre-vacuum is obtained by means of an oil-free rotary pump. The vacuum obtained by such a system is very clean and with no carbon contamination.

2.1.3 The X-ray Source System

The principal element of the system is the multi-anode microfocus X-ray source (Fig. ??) manufactured by J.E. Manson CO., Inc. Six different anodes can be selected, without breaking the vacuum in the source chamber. The source also contains selectable filters that can be used to further define the beam spectrum. It can produce X-rays in the $0.1 - 10$ keV band, with a spot size of ~ 1 mm.

2.1.4 The detectors

Two commercial Gas Flow Proportional Counters (GFPC) produced by LND, with $\sim 34\%$ energy resolution at 1.5 keV, and a Gas Scintillation Proportional Counter (GSPC)[?] with $\sim 16\%$ energy resolution at 1.5 keV are part of the basic equipment. Other detectors being part of the AXAF-HRC UV/ion shields calibration special equipment will be described in the following.

2.2 New instrumentation

In this section we describe the equipment purposely set up to perform transmission measurements, which is being employed in the calibration of the AXAF/HRC UV/Ion shield.

2.2.1 2-D Imaging X-ray Detector

A Quantar Technology MCP with resistive anode encoder and front plate coated with KBr provides 40 mm diameter active area with 100 microns spatial resolution. Its sensitivity covers the entire energy range of the facility at X-ray wavelength and extends in the UV region down to 1200 Å.

2.2.2 Transmission Grating X-ray Monochromator

The transmission grating monochromator consists of an adjustable (5-2000 microns) entrance slit (slit 1), a grating facet (1000 lines/mm), and an adjustable exit slit (slit 2) to select the energy of interest. The entrance slit and grating facet are mounted at 6.5 m from the X-ray source and 7.5 m from the exit slit and detectors. It has a resolution $\Delta\lambda \sim 1$Å and can be employed up to 2 keV.

2.2.3 Vacuum Compatible Micro-positioning System

Two linear stages with 8 inches travel are available for micro-positioning (1 μm position accuracy) of detectors and slits. An X-Y stage with 6 inches travel on each axis is used to scan the UV/Ion shields. A rotary stage is used to rotate the whole measurement assembly from the X-ray beam-line to the orthogonal UV beam-line.

2.2.4 Class 1000 Clean Room

The test chamber door opens to a class 1000 clean-room built by INTEC srl - Palermo, provided also with a class 100 laminar flow clean bench, and a dry Nitrogen cabinet for sample storage.

2.2.5 UV beamline

Figure **??** shows the UV beam-line attached on a side port of the test chamber of the XACT facility. It basically consists of a 1 meter diameter Rowland Circle mount grazing incidence monochromator (McPherson model 248/310G), a vacuum system based on a mechanical rotary pump (28 m^3/h), a turbo-molecular pump (300 l/s), valves and pressure gauges to run the system and monitor the working conditions, UV sources and detectors.

The two available gratings in the monochromator, 113 grooves/mm and 600 grooves/mm, respectively, allow a spectral coverage of 10 - 3100 Angstrom. The monochromator provides a nominal spectral resolution of nearly 2 Angstrom with the 133 grooves/mm grating.

Two UV sources are part of the equipment: a hollow cathode gas discharge source which produces a number of intense emission lines in the 200 - 2300 Angstrom range, and a pen-ray mercury discharge lamp (UVP) that provides a useful calibration line at 2537 Angstrom. The MCP covers the wavelength range up to 1200 Å, while a Photomultiplier tube with Cs_2Te photocathode and a MgF_2 window covers longer UV wavelenghts.

3 X-RAY MEASUREMENTS SET-UP

In order to carry out X-ray transmission measurements the following setup has been adopted: Manson model 5 X-ray source with C, Fe, Cr, Cu, MgO, and Al anodes, two gas flow proportional counters for spatially averaged measurements and one gas flow proportional counter plus the MPC for spatially resolved images, two linear and one X-Y vacuum compatible micro-positioning stages, an adjustable slit, a micrometer to set the position of the monochromator entrance slit and grating. Clean room, clean bench and dry nitrogen cabinet for manipulation and storage of the UV/Ion shields.

The actual configuration of the measurement assembly for spatially averaged measurements is shown in Figure ?? taken before turning the rotary table by 180 degrees to face the X-ray source. The UV/Ion shield fixed to the X-Y table with stainless steel brackets can be moved along a vertical plane in between the slit and the measurement counter (not visible, behind the UV/Ion shield). The UV/Ion shield is located 40 mm away from the adjustable slit and 20 mm away from the measurement GFPC. Both the slit and the measurement GFPC can be moved along the vertical direction by means of two linear stages. A second GFPC mounted on a fixed bracket on top of the measurement assembly monitors the X-ray source flux. A mask with a small central aperture was mounted in front of the entrance window of the monitor proportional counter in order to reduce the illuminated area and thus the count rate to keep the dead time below 10%.

The two gas flow proportional counters were operated with P10 gas (10% Argon + 90% Methane) at 300 torr pressure. The HV of the counters and amplifier settings have been chosen for each anode in order to nearly center the line of interest in the MCA spectrum.

In order to conduct measurements with the transmission grating monochromator, the entrance slit together with the grating was placed in the beam and aligned using a laser source. Different energies were selected moving the entrance slit and grating along the (vertical) dispersion direction, by means of a precision micrometer. Figure ?? shows the spectrum of the Cu anode taken without (top) and with the monochromator (bottom), respectively, demonstrating the performance of the monochromator.

In such setup, one of the GFPC can be replaced by the MCP. This determines a lower measurement accuracy because of the loss of spectral information, but spatial resolution is achieved, which allows to test spatial uniformity within the illuminated area. In addition, removing the monochromator and the slits, it is possible to fully illuminate the MCP, making a so-called shadowgraph of the UV/Ion shield. Usage of filters to better define the beam spectrum is necessary when the monochromator is not used. Although it is not possible to achieve the accuracy reachable with the monochromator in determining the absolute value of transmission, the shadowgraph is a very useful uniformity test yielding fast information on spatial transmission variations.

4 UV MEASUREMENT SET UP

The measurement assembly inside the test chamber described above is mounted on a rotary table so that a rotation of 90 degrees from the X-ray beam-line allows the detectors and shield to be pointed towards a side port where the UV-beam-line is attached through an isolation gate valve. The UV beam-line consists of:

- A 1.0 m diameter grazing incidence monochromator, McPherson Model 248/310 G, with 113 grooves per mm grating;
- Two interchangeable UV sources: 1) a windowless hollow cathode source, McPherson model 629, to cover the wavelength range 200-2300 Å, and 2) a mercury lamp to provide a bright line at 2537 Å.
- Two interchangeable photon counting detectors: 1) a micro channel plate (MCP) with front plate coated with KBr for wavelengths shorter than $\sim$ 1200 Å, and 2) a Far-UV photo-multiplier tube (FUV PMT) with a cesium telluride photo-cathode for use at wavelengths longer than 1200 Å.
- three film holders to insert neutral density meshes and filters;
- A vacuum system consisting of a rotary pump, a turbo molecular pump, a differential pumping assembly, pressure gauges and valves to monitor and control the pressure in the beam-line and regulate gas pressure inside the hollow cathode source.

The exit slit of the monochromator, a baffle to prevent stray-light, and the detector are aligned using a laser tube mounted in place of the hollow cathode source. When the monochromator is set to minimum chordal distance between the source and the grating, the angle of incidence of the beam passing through the entrance slit is 87 deg. which is nearly the same as the fixed angle of diffraction from the grating to the exit slit (87.08 deg.). In this configuration the zeroth order of the laser beam traces the path of the diffraction beam and can thus be used to align the instrumentation before evacuating the test chamber. Fine alignment corrections can also be done under vacuum with the UV source ON maximizing the flux measured with the detector. Vertical corrections are accomplished moving the detector which is mounted on a micro-positioning linear stage; horizontal corrections are accomplished moving the UV beam-line attached to the test chamber through a bellow with adjustable stainless steel spacers also providing rigidity when the beam-line is under vacuum.

The stray-light baffle with 1 cm diameter hole is located half way between the monochromator exit slit and the detector providing an illuminated area up to 2 cm diameter at the detector plane. Two neutral density meshes manufactured by Micro-tech s.r.l. (Palermo) by etching of copper foils are mounted in the two filter wheels located behind the monochromator exit slit. In order to reduce the incident flux when the UV/Ion shield is out of the beam, the two meshes can be inserted in the beam path one at a time or together. When both are inserted, they provide a flux reduction of nearly 0.004.

When using the MCP (below 1200 Å) the background noise level may be affected by electrons or ions hitting the detector front plate. This is particularly critical when a high flux of UV photons illuminates the UV/Ion shield stripping a large number of electrons from the aluminum surface. In order to reduce the noise to the level of the intrinsic detector background (of the order of 5 cts/s over the entire sensitive area at 1 10^{-6} $mbar$ pressure in the test chamber) the shield was maintained at an attractive potential (1000 V) with respect to the front plate. In addition, a mesh was installed in front of the MCP (40 μm wires at 220 μm pitch) biased with repulsive potential (-100 V).

The FUV PMT was biased with negative high voltage on front Cs_2Te coated dynode and ground on last dynode in the multiplication cascade. In order to prevent discharges between high voltage area of the FUV PMT and the UV/Ion shield, the latter was biased at the same voltage as the front PMT dynode.

5 CONCLUSIONS

We have described the instrumentation set up at XACT facility for the calibration of the AXAF-HRC UV/Ion shields. The instrumentation allows to perform UV rejection measurements in the wavelength range 200-2550 Å and X-ray transmission measurements in the energy range 0.1-10 keV. The usage of monochromators allows to cut-of the continuum in the spectra of X-ray and UV sources, isolating the line contribution, which results in a big improvement in accuracy with respect to measurements taken with no monochromator. The facility features an excellent cleanliness for the oil free pumping system and the class 1000 clean room to which the test chamber opens.

6 ACKNOWLEDGEMENTS

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7 REFERENCES

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8 FIGURES

Figure 1: The beam line, including the pipe, the X-ray source at the right end and the test section, in the background at the left end.

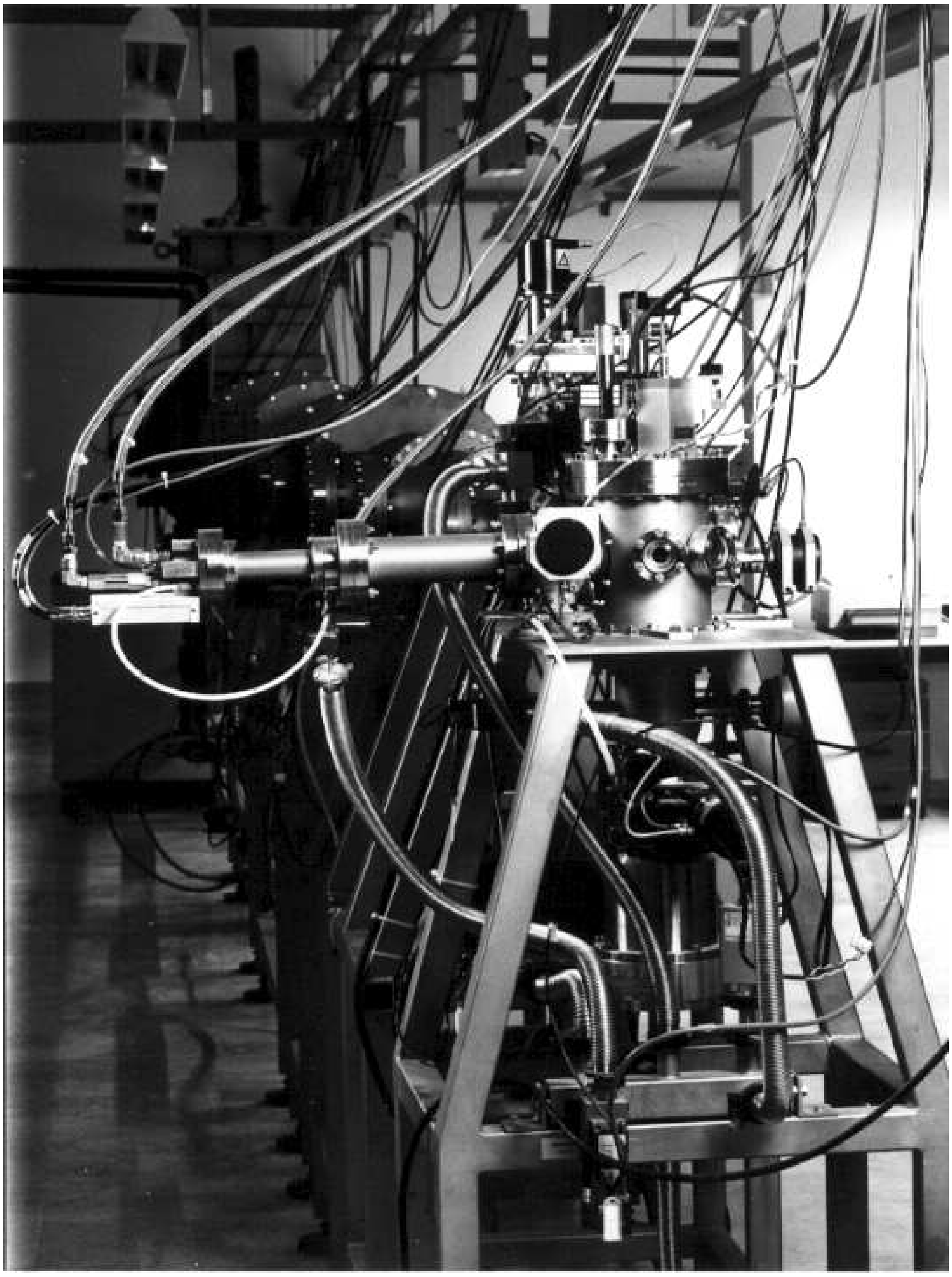

Figure 2: The X-ray source. The tube on the left is a secondary beam that can be used for monitoring.

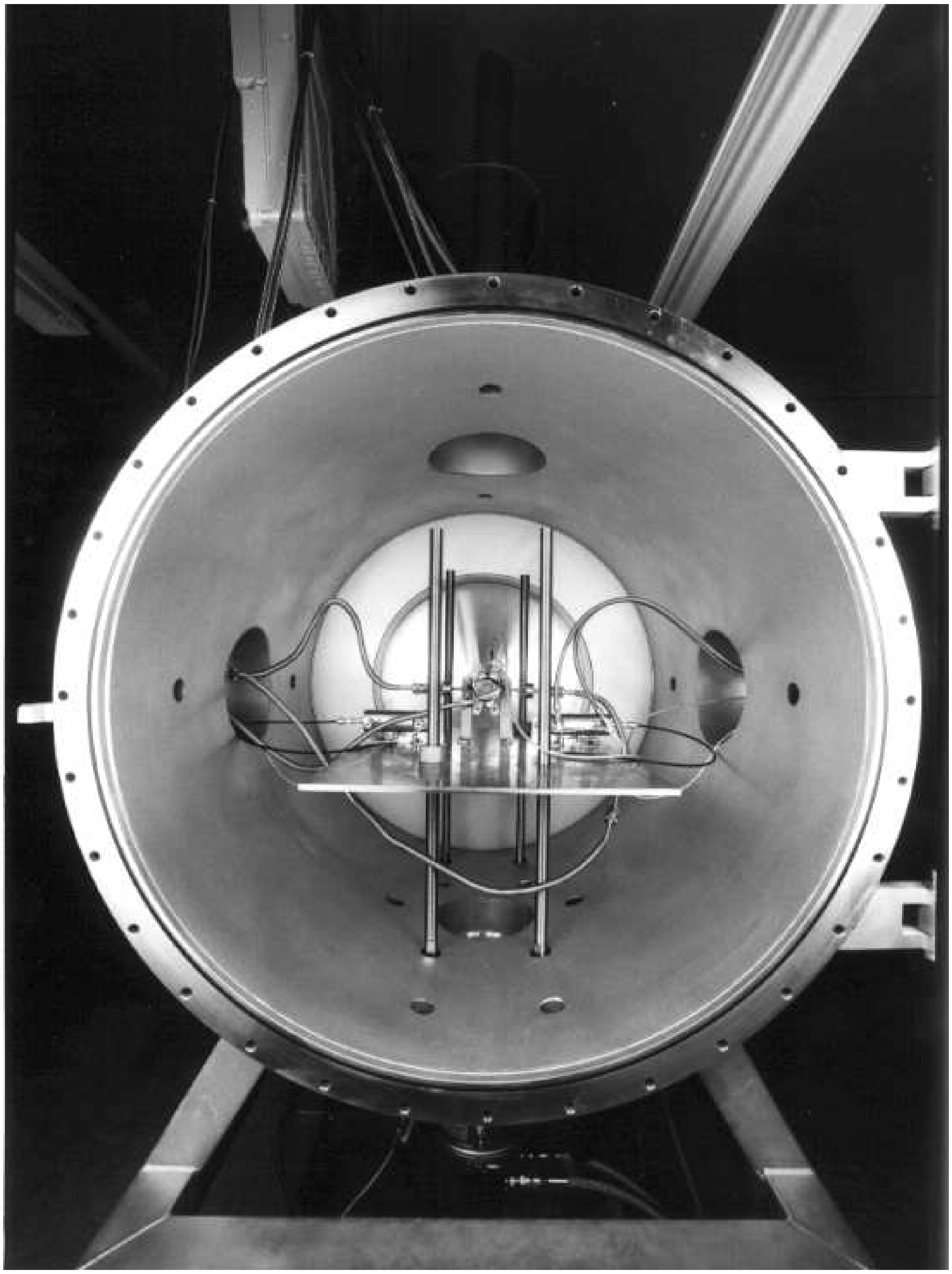

Figure 3: Inside of the test section in its basic configuration. Two GFPC and a GSPC (in the center) are mounted on the stainless steel table

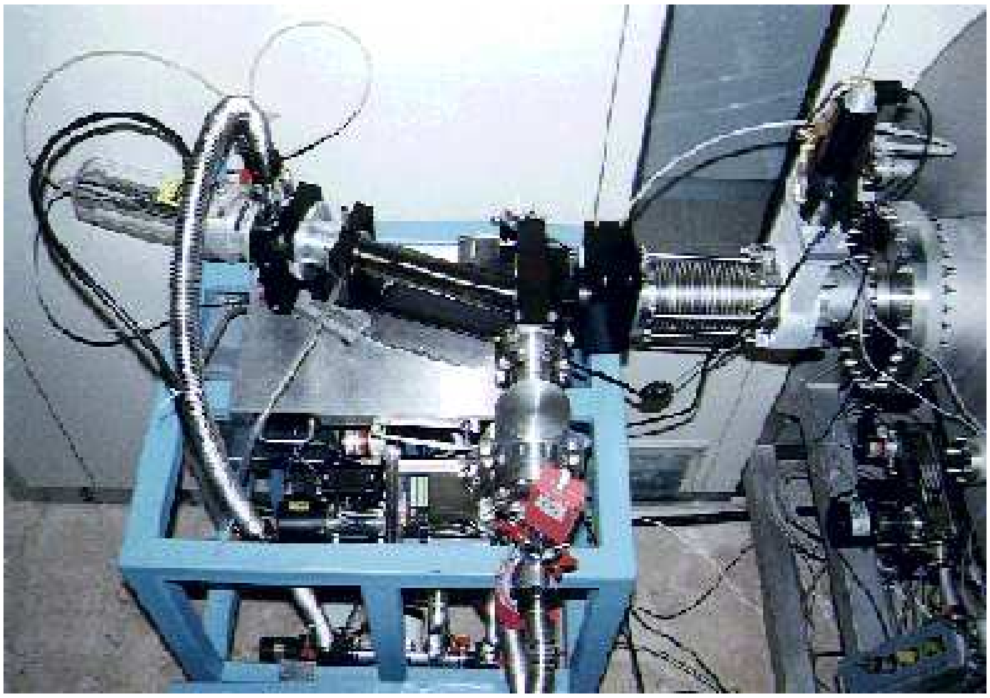

Figure 4: Picture of the UV Beam-line attached on a side port of the test chamber of the XACT Facility. Notice in the background the wall of the class 1000 clean room sealed around the test chamber.

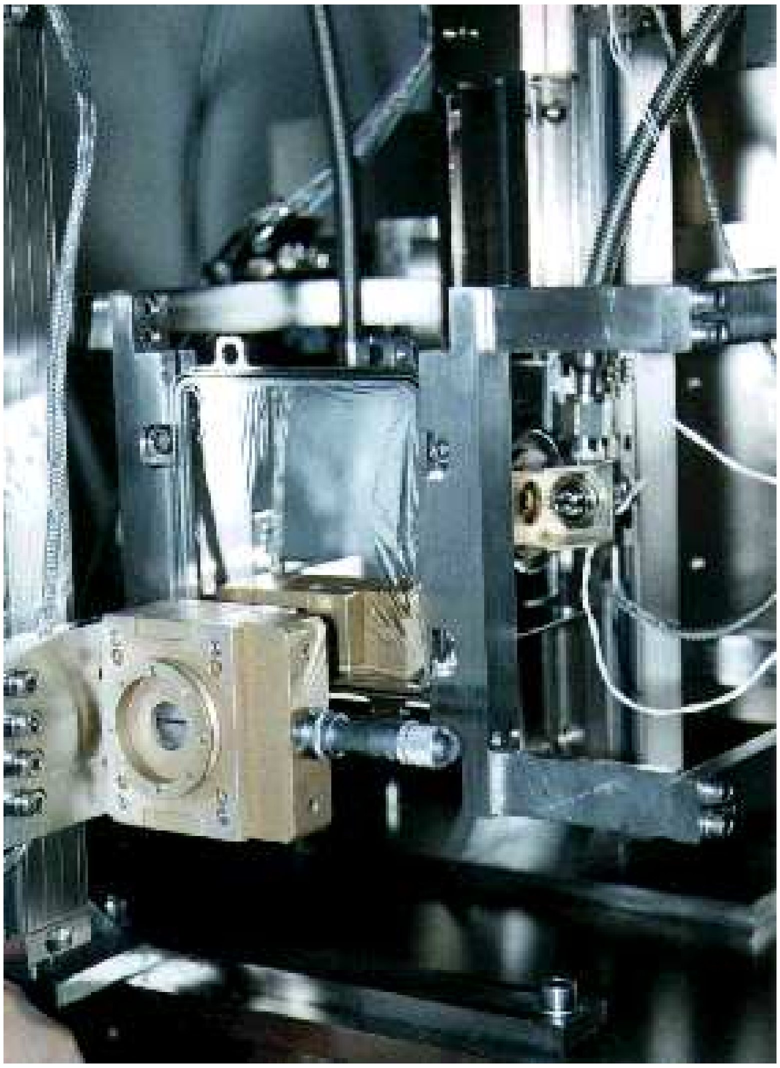

Figure 5: Front view of the instrumental assembly. Notice the UV/Ion shield and, in foreground, the exit slit of the X-ray monochromator.

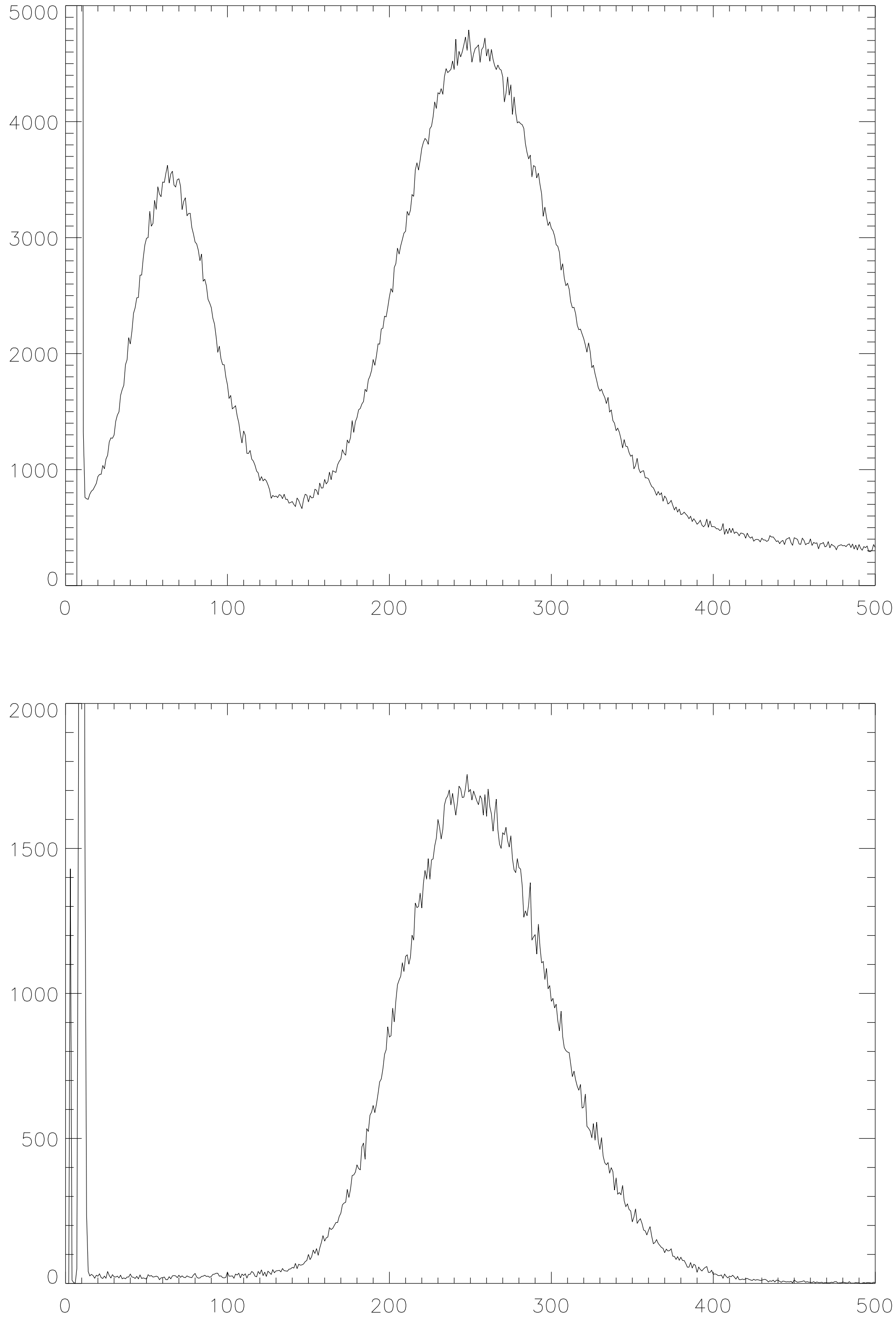

Figure 6: Multi channel analizer spectra of Cu anode taken without (top panel) and with (bottom panel) the transmission grating monochromator. The entrance slit was set to 0.5 mm aperture.