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di Firenze

Dipartimento di Astronomia
e Scienza dello Spazio

XUVLab
Activity Summary Report 2002

Technical Report TR5-2002

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Contents

1. Introduction

XUVLab is an experimental laboratory of the Department of Astronomy and Space Science (DASS) of the University of Firenze (see XUVLab 2001).
2002 has been an exciting year for the activities of the XUVLab. New instrumentation setup, new facilities, definition of new challenging projects, new national and international collaborations, people visiting our lab and contributing with their important expertise, involvement of students in the experimental activities represent some example of the achievements and interactions occurred during the last year.
The experimental activities have been revised and then focused on four main topics:

- Material characterization and processing technology to develop innovative UV and X-ray photon detectors. Devices have been produced and studied to improve their performance.
- CCD and CMOS detectors for visible and ultraviolet applications. New cameras and controller electronics have been developed and proposed for solar and laboratory experiments.
- Solar space missions. These activities include UV polarimetry, optical design, study of the stray light due to the optical system and the related reduction techniques, detector developments
- EUSO experiment on the International Space Station. The XUVLab group is responsible for the UV testing of the focal plane detectors and the definition of the UV filters.

Instrumentation developments have enlarged the number of facilities available at the XUVLab for the characterization and the calibration of optical systems and detectors as well as for material and detector fabrication and processing. The new facilities are:

- a clean room for material and device processing;
- a clean room for optical measurements;
- a laboratory for characterization measurements of the EUSO components, in the framework of the activities with the National Institute of Nuclear Physics (INFN).

The number of researchers, which have joined the XUVLab group, has increased and their efforts have produced a stronger impact on the research activities. The programs and the instrumentation developments have also benefited from the interaction with other experimental groups in terms of new European and national projects, space experiments and exchange of knowledge and information.
Furthermore, the XUVLab team has joined, besides the INFN, the National Institute of Matter Physics (INFM) by partecipating to a challenging national project on wide bandgap materials

that paves the way for a Research Center on Advanced Materials for Radiation Detectors that will be based in Florence, but possibly extended to other national institutes and research groups. Training and educational activities for students and future scientists is still one of the main tasks of the XUVLab. This has been mainly achieved through doctor thesis, Ph.D. and Post-doc positions, grants and fellowships. Some of the researchers give lectures on these arguments and the laboratory is available for experimental training of undergraduate students that wish to include Astrophysical Techniques in their curriculum. Shortly, the XUVLab WEB page will be available. There, the students will find a dedicated page providing a useful instrument to get information, tutorials and suggestions.

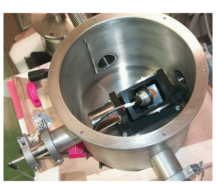
2. XUVLab Instrumentation

The XUVLab is equipped with instruments and devices for VUV spectroscopy and optical characterization, detector development and testing, and analog and digital electronics. This equipment is also supported by a computation facility, specifically designed and developed at XUVLab for laboratory instrument control, data analysis, and optical ray tracing. All equipments and facilities are hereafter described. Instruments acquired in 2002 are pointed out.

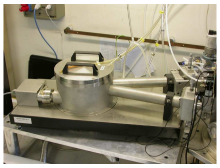
2.1. VUV and visible light calibration and testing facility

The calibration and testing facility has the capability of performing spectroscopic and polarimetric measurements in the normal incidence wavelength range from extreme UV (30 nm) to near infrared (1100 nm) aimed at testing and characterizing detectors and optical components. The vacuum in the calibration chambers is produced and maintained by oil-free pumps.
The facility is equipped with:

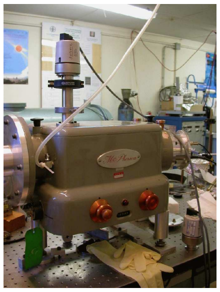
High vacuum calibration chamber for optics and device testing. It consists of a 50 liter chamber (a cylinder of 0.4 m diameter and 0.4 m height) equipped with two coaxial electrically driven motors that drive, respectively, a horizontal platform and a vertical arm, on which detectors and optical components can be mounted and moved. The chamber is evacuated using a dry Scroll pump and a cryogenic pump down to $\sim 10^{-7}$ mbar.



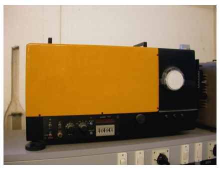
VUV polarization analyzer It consists of a small vacuum chamber customized for a linear polarization analyzer. The linear polarization analyzer consists of a flat reflecting plate and a detector, mounted on a motorized assembly that rotates around the incidence optical axis. The incidence angle on the plate can be manually adjusted in the range from 45° to 70°. The analyzer is optimized for the $90 \div 130$ nm wavelength range.



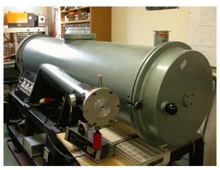
0.5 m normal incidence Johnson-Onaka vacuum monochromator (Cinel) for VUV wavelength band (> 30 nm), equipped with spherical grating (600 lines/mm, blazed at 150 nm, Pt coated).



0.3 m normal incidence Czerny-Turner vacuum monochromator (MacPherson, mod. 218) for VUV wavelength band (> 120 nm), equipped with 5 plane gratings having different blaze wavelength: 600 lines/mm, blazed at 120 nm, Al+MgF_2 coated; 600 lines/mm, blazed at 1 μm, Al coated; 1200 lines/mm, blazed at 200 nm, Al+MgF_2 coated; 1200 lines/mm, blazed at 1 μm, Al coated; 150 lines/mm, blazed at 4 μm, Al+MgF_2 coated.



0.5 m Czerny-Turner monochromator (Cinel) for visible light (> 200 nm), equipped with a plane grating.



2 m normal incidence vacuum spectrometer (Cinel) for VUV wavelengths (> 30 nm), equipped with a spherical grating (Jobin-Yvon, 2400 lines/mm, Pt coated).

Radiation sources

- 2 Hollow Cathode Sources (manufactured by Cinel and MacPherson, mod. 631) for VUV and UV spectral line radiation.
- Deuterium lamp (Hamamatsu mod. L7293) for continuum UV radiation from 115 nm to 400 nm.
- Spectral line UV lamps: Cd (BHK Inc., mod. 89-9020-21), Zn (BHK Inc., mod. 89-9020-01), Hg (Hamamatsu, mod. L1834).
- 2 He-Ne lasers (Spectra-Physics, mod. 155).
- New-2002 Hg-Xe 1000 W lamp (Oriel Corp.)

Detectors

- Calibrated NIST windowless photodiode for the 5$\div$ 254 nm wavelength range.
- Calibrated NIST windowless photodiode for the 17.5$\div$121.6 nm wavelength range.
- New-2002 Calibrated photodiode for the 200$\div$1200 nm wavelength range (Hamamatsu, mod. S2281-01).
- Channel electron multiplier (CEM) (AMPTEK, mod. MOD-501 AMPTEKTRON)

- Several single- and multi-anode photomultiplier tubes (Hamamatsu, EMR) for analog and photon-counting readout.
- CCD cameras with several CCD sensors.
- 2 CMOS imagers (Fill Factory, mod. Fuga 1000 and IBIS) having linear and logarithmic response.
- Single pixel silicon photodiode.

Equipment for vacuum

- Cryogenic pump (CTI-Cryogenics, mod. Cryo-Torr 8).
- 2 dry Scroll pumps (Varian, mod. Triscroll 300).
- Membrane pump (KNF, mod. N880.3AN.22E).
- 2 turbo-molecular pumps (Edwards, mod. EXT70H).
- Turbo-molecular pump (Pfeiffer Vacuum, mod. TMH 071 P).
- Turbo-molecular pump (Edwards, mod. EXT501).
- Turbo-molecular pump (Varian, mod. Turbo-V 1000HT).
- New-2002 Turbo-molecular pump (Varian TV301 Navigator, mod. 969-8918 ISO-DN100).
- Turbo+dry pump (Alcatel, mod. Drytel Micro).
- New-2002 Primary dry pump (Varian, mod. Triscroll 300).
- Quadrupole for residual gas analysis (Pfeiffer Vacuum, mod. Prisma80-QMS200).
- Vacuum gauges (Pirani, Penning, Full-Range, multi-gauge by Pfeiffer Vacuum and Varian).
- New-2002 Gate valve, mod. VAT ISO-KF25.

Optical bench equipped for optics and device testing in visible radiation.

Theodolite-Digital Total Station (Nikon, mod. DTM-1) for optical alignments.

Laminar flow bench (Bassaire mod. A3VB).

2.2. Laboratory for detector development in cleanroom

A 30 m^2 clean room laboratory (class 100000, see figure 1) devoted to photolithography and material and device processing has been installed at DASS with the aim of fabricating photon detectors on advanced materials. The equipment consists of:

Bonding machine (Delvotech, mod. 5430).

Mask aligner (Cobilt, mod. CA800).

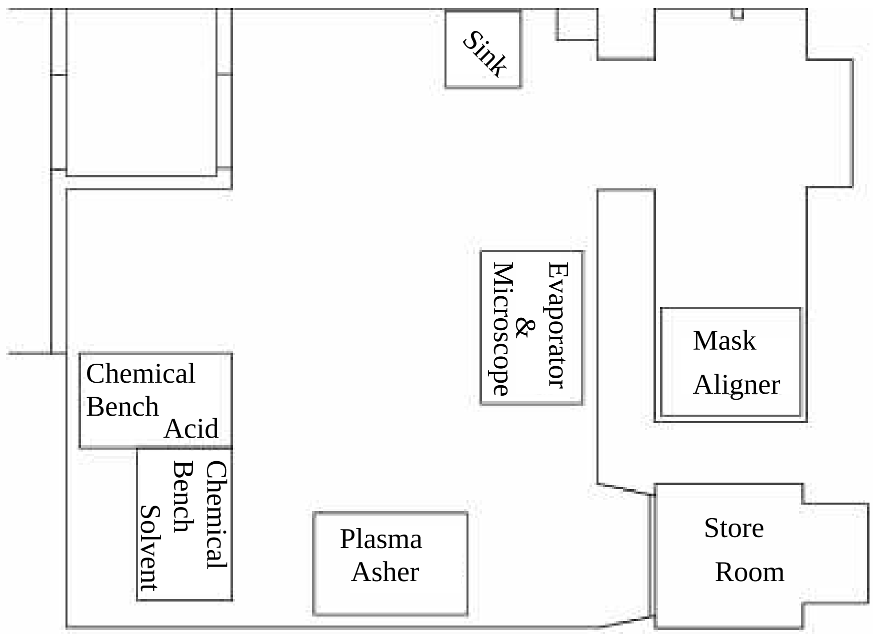


Figure 1: *Plan of the clean room.*

Evaporators for metals with one crucible and two electron guns (Leybold).

Microscope (Leica, mod. MZ6).

Tubular oven (LaborChimica, mod. CTF 12/75/700 Plus).

New-2002 **Spinner** (Spin Coater, mod. 6700).

New-2002 **Heaters** XUVLab assembly with Eurotherm thermal control, mod. 2132.

The room has been prepared by covering the walls and the floor with a special plastic preventing dust formation and by reducing the presence of corners. The ventilation system assures more than 20 change/hour of the whole air volume inside the room; thus, the particulate density decreases for dilution.
The room entrance is through a double door allowing special clothes dressing before entering the clean environment. The room is composed of three parts: the main room, the mask aligner room, separated by a special curtain to improve the air quality locally, and a small storeroom. Supplies of water, de-ionized water, gas lines (purified compressed air, nitrogen and argon), and vacuum pumps are available.
Equipment for photolithographic process is already on site. Two chemical benches, one to work with acids and photoresist, the other with solvents, allow safe preparation and processing of the samples. In particular, the chemical bench for solvents is provided with a spinner having selectable rotation speed, heaters with precision thermal control, and chemicals in order to spread, process and remove the photoresist. The Mask Aligner, exposing the photoresist to the desired geometry of electric contacts by means of UV light, is placed in the cleaner part of the room

on a table, specifically designed to assure stability and to reduce vibrations. Other instrumentation presently available is a semi-automatic wedge-bonding machine, an optical microscope and a self-made evaporator that is available at the National Institute of Nuclear Physics (INFN). The first months of 2003, the equipment of the XUVLab clean room will be completed adding a new evaporator, a plasma asher that removes any organic contamination from the surface of the samples, and a more powerful microscope supporting the Nomarsky-type magnification for visual analysis of material samples and after-processing electronic structures.

2.3. Laboratory for analog and digital electronics

The XUVLab has a facility for the development of analog and digital electronics, in order to support the detector development activity and, in general, the laboratory activity. This facility has instruments and software products that make possible electronic board design and development, development of electronics based on micro-controllers and programmable logic devices, fabrication of detector controllers. The equipment consists of:

Digital Oscilloscope 2 Gsample/s, 1GHz bandwidth (LeCroy, mod. LC574A).

Multi-channel logic state analyser (Tektronix, mod. TLA601).

2 Wave generators (HP, mod. 33120A).

2 Digital counters (Agilent, mod. 53131A).

HV/LV power supplies (Stanford, mod. PS350; TTi, mod. EL302D; etc.).

Electrometer with sensitivity 0.1 fA (Keithley, mod. 6517).

2.4. Computer facilities

The XUVLab is equipped with several personal computers, that form the XUVLab network, part of the Osservatorio di Arcetri network. They are operated under Microsoft Windows (NT, 98, 2000, ME), and Linux. The computation facility is equipped with software for laboratory equipment control (LabV VIEW 6i) (Puri et al. 2000), data analysis (Origin and IDL), optical ray tracing (Zemax 9.1 and free access to Opticad 8.0), CAD design of instrumentation components (AutoCAD 14), and programmable array and microprocessor design (XILINX Foundation, ORCAD).

2.5. Mechanical workshop

A mechanical workshop is a shared facility available at DASS. Expert technicians and equipment allows the fabrication of high quality instruments and accessories. XUVLab researchers have designed vacuum chambers, instrumentation, CCD cameras, housings for detectors optics and radiation sources, vacuum accessories that technicians have produced at this mechanical workshop.

3. XUVLab ongoing activities

3.1. Detector developements

3.1.1. Diamond detectors

The use of wide bandgap materials to fabricate UV detectors is one of the main research activities at XUVLab. This is focalized on synthetic diamond and recently on bidimensional array detectors. The research moves along two parallel directions:

- The selection of the most sensitive material among different types of presently available synthetic diamonds.
- The feasibility study of 2-D sensors; in particular pixel geometry, array geometry, readout and signal reconstruction are investigated.

The physical and electro-optical properties of homoepitaxial and eteroepitaxial, CVD (Chemical Vapour Deposition)and HPHT (High Pressure High Temperature) diamond are studied in order to select the suitable material.
Samples have been made available by commercial sources (like De Beers Industrial Diamond, Fraunohofer Institute of Technologies or Sumitomo) or by other research groups (Dip. Scienze e Tecnologie Fisiche ed Energetiche of the University of Roma Tor Vergata and the University of Augsburg). The quality of the crystals and the presence of graphite in the grain boundaries, as well as the impurity and defect content is assessed using Raman and photoluminescence spectroscopy. A couple of gold planar contacts is evaporated on selected films to fabricate photoconductive devices (see figure 2); then, electrical and optical measurements are performed using UV and visible monochromatic illumination.
Typically, spectral responsivity, spectral photoconductivity, and electrical characteristics are measured (C7). Illumination transients provide information on the time response and its dependence on material typology, voltage biasing, wavelength, temperature, and radiation intensity. The aim of these characterizations is the study of the correlation between sensor performance and structural properties of the material, providing also a feedback to the manufacturer that improves the film quality with a benefit for the detector performance.
Recently, particular care was taken over the performance of photoconductors based on monocrystalline CVD diamond grown on a 1b-type HPHT diamond substrate, because of the novelty of such a detector. The present experimental results lead to believe that single crystals (HPHT or CVD) allow enhanced sensitivity and faster time response with respect to polycrystalline diamond films, even if the quality of the last ones is improving and their cost lowering.
Another experimental activity is addressing the feasibility study of imaging detectors based on diamond films (BOLD collaboration and an ASI project) (A4; C4). Electro-optical measurements have been performed on devices with a sandwich electronic structure. The use of this electric contact configuration is simpler than planar contacts, because pixels can be packed filling the whole film surface. Unfortunately, the optical and electrical properties of diamond produce effects, such as space charge and polarization, which reduce or affect the responsivity and the time behavior. Therefore, research is going on, studying possible arrangements of

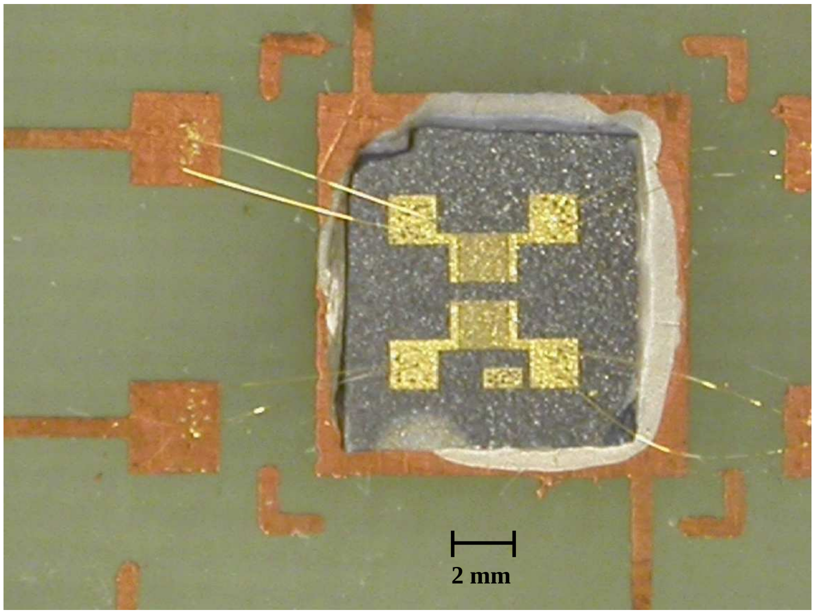


Figure 2: *Example of photoconductive device based on diamond.*

planar contacts to form pixel arrays and investigating the material properties to find out a sandwich electronic structure that solves the mentioned problems. 5 x 2 pixels array prototypes have been produced to study their functional features, such as multiple readout, cross-talk between adjacent pixels, and signal acquisition and processing.

Diamond detectors Summary	
Material Selection	Raman and photoluminescence measurements on samples. Gold planar contacts evaporated on each sample. Realization of a photoconductor device on a mono-crystal CVD diamond. Electrical and opto-electrical measurements on photoconductor devices.
2-dimensional sensors	Measurements on sandwich-geometry electrodes. Realizatoin of a 5x2 pixels matrix.

3.1.2. Charged coupled devices (CCDs)

The main activity of the XUVLab's CCD research group is the design and implementation of a new concept CCD camera which is currently at the final test step. This CCD camera is useful for wide-band photometry and spectrophotometry, and it will be the detection system for the broadband visible light polarimetric channels of the coronagraphs of HERSCHEL rocket flight space mission (Gori et al. 2001; C6) (see section 3.3.3) and for ground-based polarimetric observation of the Sun. The main features of this camera are a high level versatility and a fast pixel rate that will satisfy the requirements of both the experiments. Within this project, the versatile CCD controller has interesting and innovative features: it allows the selection of all the parameters related to the CCD readout and charge transfer; therefore we can virtually use any CCD sensor. The new camera head is also versatile and compact and is based on a modular package, providing simple and fast upgrade of the camera head. Its closed-loop liquid exchanger circuit allows the portable scientific camera to cool down to -75 °C.

The Controller is the main part of the CCD camera, since it generates the readout clocks, it controls the data transfer to the PC and it manages other functions like temperature monitoring, motor controller (telescope, gratings, optics), gain selection, bias generation and shutter or laser triggering. The XUVLab has developed a portable controller which includes several boards: the sequencer, the clock driver, the bias generator, the Correlated Double Sampling (CDS) circuit, the ADC converter, the opto-couplers and the power supplies. All these circuits have been upgraded, re-designed and implemented in a few boards which are now included in a compact case (440 mm X 180 mm X 300 mm).

The most important contribution to the versatility of the CCD camera is given by the sequencer. The sequencer produces the digital clock waveforms and some digital signals to control the frame acquisition; moreover it sets parameters such as the exposure time, the frame format, and the acquisition of multiple images. The heart of the flexible sequencer board is a Hitachi microcontroller which inizializes three logic devices (Xilinx CPLDs) and which is interfaced to a PC via RS232 serial port (Gori 1999; Gherardi 2002). The digital clocks are converted into analog clocks through the clock driver, whose voltage levels are set according to the specific sensor, while the bias generator circuit produces the bias voltages for the output stages of the CCD sensor. Such arguments are part of the Doctor degree thesis of Alessandro Gherardi (Gherardi 2002). The CDS circuit eliminates the "reset" noise, the ADC converts the analog video signal into two bytes and the opto-couplers reduce the number of the noise sources and their amplitude, insulating the CCD camera controller from the PC. The ADC is a 16 bits DATEL with 2 MHz sample frequency; the data transfer from the controller output to a PC is achieved via parallel readout: it has been used a National Instruments very fast DAQ (Data Acquisition) board with 32 MB on-board memory which achieves high-speed pattern I/O at rates up to 80 MB/sec.

The XUVLab has arranged some facilities to produce the mechanical parts of the CCD camera, like the camera head (detector housing and cryogenics). The camera head is composed of 5 versatile modules that allow a simple connectivity. The developed CCD camera follows some innovative design concepts: the modular package is versatile and compact (size: 120 mm length and 90 mm radius), and includes two modules for the proximity electronics, a module with a Peltier thermoelectric cooler (under vacuum), a module with liquid heat exchanger and a module for the CCD sensor sealed by a quartz window (see figures 3 and 4) and provided with a flange to evacuate the head at 10^{-6} mbar. This last feature is particularly required for UV and VUV CCD applications to reduce the contaminant content. The total camera weight is less than 1.5 Kg.

The software interface ("CCD Acquisition Program") is based on the LabVIEW 6i platform (National Instruments). The LabVIEW interface is used to start-up CPLDs, and to acquire and

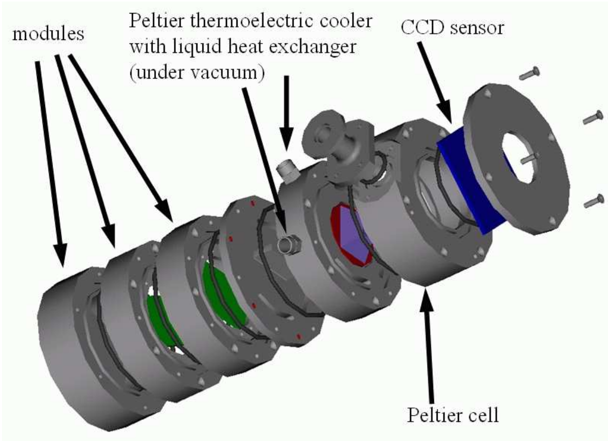


Figure 3: *The modular package of the CCD camera head.*

Figure 4: *CCD camera head. ø=9 cm; height=12cm.*

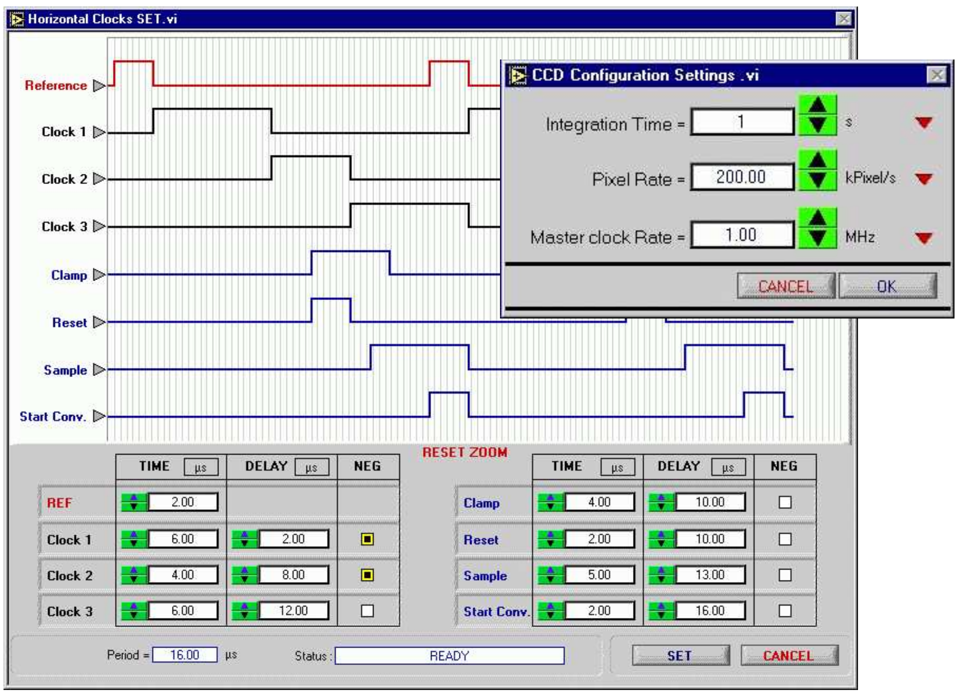


Figure 5: *Two examples of LabVIEW panels to set the CCD camera parameters. They highlight one of the new features of the software interface: the capability of real-time setting clocks.*

view images. Within some adjusting panels (see figure 5) the user can set, by editing the values, the clock durations and shifts, the integration time, the pixel rate, the master clock frequency and the CCD format (Puri et al. 2000).
The XUVLab has developed a novel feature of the software interface: the capability of viewing the shapes of the clocks just set directly on screen; this is essential to allow novice users to easily

configure the CCD parameters by comparing the clock shapes with the CCD specifications. It is possible to save and load default parameters or other configurations. The CCD Acquisition Program is also provided with an Image Manager tool, which allows to view the acquired image in gray scale or in false colors, to save it in several formats, to make some statistic operations and to select a sub-frame of any shape to analize it (Gherardi 2002). The development of the camera will include the LabVIEW 6i implementation of remote link mode to manage the camera through TCP/IP via a LAN or via Internet.

CCDs Summary	
CCD camera controller	Clock driver. Bias generator. Correlated Double Sampling circuit. ADC converter. Opto-couplers. Assembly of a new portable case.
CCD camera head	Modular package (including the new module with the closed loop liquid heat exchanger).
Software interface	Shapes of the clocks shown on monitor. Image Manager.

3.2. Optical design and testing

3.2.1. Optical simulation

EUSO optical adapters - The EUSO detector (see section 3.3.4) needs a suitable optical adapter, in order to improve the collection of photons from the image produced on the focal plane by the main optics. The reduced efficiency is caused by a sensitive area of the detector smaller than its actual dimension.

Several options to recover the geometrical acceptance of EUSO detector have been suggested. The primary goal of an optical concentrator placed in front of each EUSO photomultiplier is to provide the suitable demagnification that will enable to recover the geometrical acceptance of the MultiAnode PhotoMultiplier Tube (MAPMT). XUVLab has studied, in collaboration with the National Institute of Applied Optics (INOA), several solutions to define the design of the optical adapters. One of them is the use of small lenses as a concentrator before EUSO detector. Hemispherical lenses coupled to the 64-channel photomultiplier have been optimised, taking into account the main telescope design and the accommodation of the detector on the focal surface. The calculated efficiency is low. Therefore, the Winston cone has been investigated and the efficiency has improved (Mazzinghi 2002). Another solution, that should improve the collection efficiency, as well as the mass budget is under evaluation and consists of a special light collector coupled to an electrostatic focusing photomultiplier (see figure 6).

Optical computer simulations, performed with Zemax 9.1 non-sequential surface ray trac-

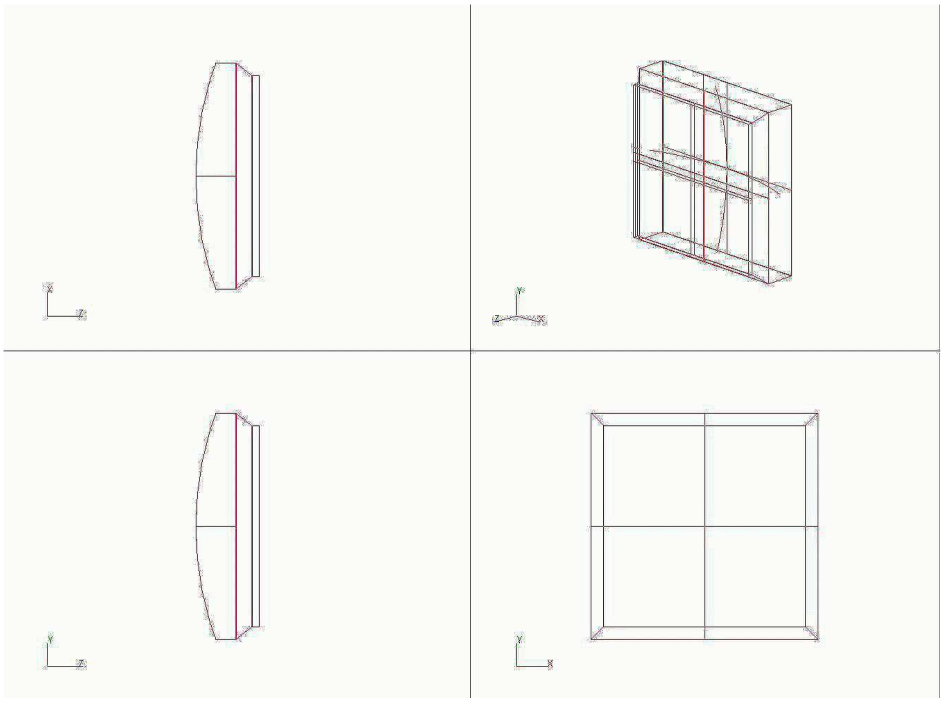


Figure 6: *Views and sections of the filter lens for EUSO.*

ing, have been also used to evaluate a special filter designed by the RIKEN group in Japan (Kawasaki et al. 2002). This filter is a BG3 filter glass shaped as a truncated pyramid and coupled to a multi-channel photomultiplier. This peculiar shape combines the filtering action with the collection of photons, using the total reflection from the inclined side walls (T1).

The simulations have shown that they are very effective coupled to the electrostatic focusing photomultiplier, while they cannot be used with a normal one. Moreover, tracks have been simulated to evaluate the imaging capabilities of such light collector and to evaluate the effects of the pixel size on the track reconstruction.

This work is subject of a Doctor Degree Thesis, due in 2003.

EUSO stray light - EUSO (see section 3.3.4) aims to detect the fluorescence produced in the atmosphere by ultrahigh energy cosmic ray particles impacting the Earth atmosphere. The cosmic ray produces an electromagnetic shower that moves through the atmosphere, which induces nitrogen fluorescence in bands around 337 nm, 357 nm, and 391 nm. Other processes that produce emission in this wavelength range will contribute to the background against which the signal must be seen. The detection of the signal is triggered by the beginning of the event

and is marked by a count rate that exceeds a fixed threshold, and the resulting event looks like a narrow track in which the recorded amount of light is proportional to the energy of the cosmic ray. As long as the background stays below this threshold, no matter whether it varies, EUSO will be able to detect all the cosmic rays above a threshold energy.
The source of background in the wavelength band from 300 nm to 400 nm are of natural origin, and manmade origin. The antropic sources are city lights and lights from ships and planes. The natural sources are transient phenomena like the aurorae and the lightnings and constant phenomena, like the nightglow produced by atom-atom collisional excitations and ionic recombination from O2 bands, or moonshine reflections by clouds or by the Earth surface. Some of these O2 sources are localized but they can be so intense that the stray light produced inside the telescope will hinder the measurements.
An optical simulation has been performed, using a simplified optical configuration for the EUSO telescope, to determine what is the maximum tolerable level of background stray light, and to design the optical baffling system (T4). The optical simulation was performed with Zemax 9.1 non-sequential surface ray tracing (see figure 7).
The analysis shows that the background radiation does not trigger the signal threshold when

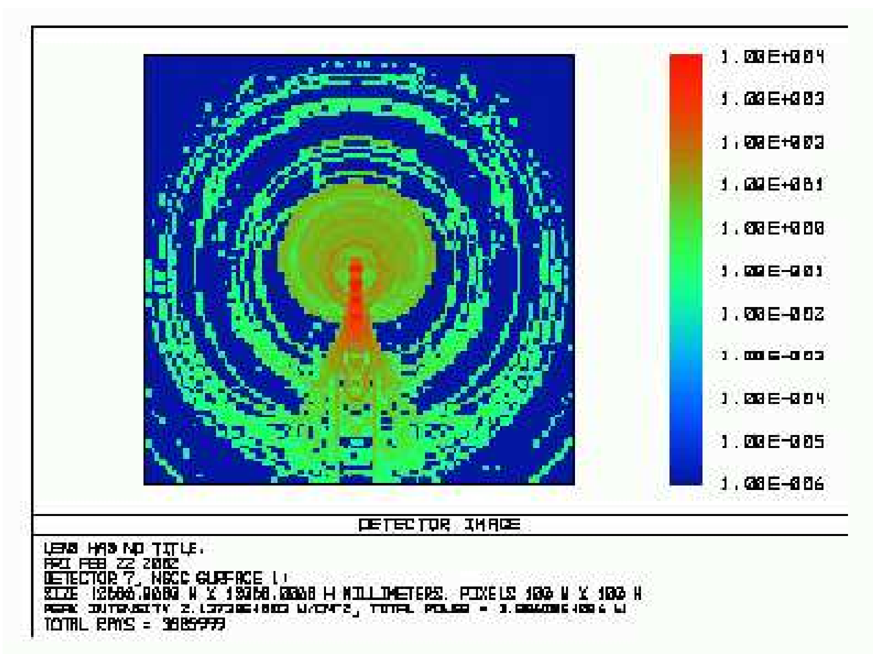


Figure 7: *Example of simulation result for EUSO stray light analysis.*

city lights are not in the field of view. Stray light is produced by the optics and rather omogeneously scattered on the image plane. Nevertheless, the stray light produced by a source of light with intensity above 100000 counts/ms can go above the threshold, and observations performed during the pass of this source across the field of view must be avoided.
The same ray tracing analysis can be performed again once the specifications of the telescope optics will be finalized, in order to determine the stray light requirements for EUSO.

HERSCHEL stray light - The UVCI coronagraphs for the HERSCHEL mission (see section 3.3.3) are designed to image the visible and ultraviolet coronal emission, in order to diagnose the solar corona. The coronagraphs have the same optical layout, which is characterized by an all reflection off-axis gregorian telescope. The UVCI is designed to obtain monochromatic images of the corona in the HI Lyα 121.6 nm and HeII Lyα 30.4 nm lines, and to measure the polarized brightness of the K-corona in broadband visible light.
One of the most stringent requirements in the design of a coronagraph is the stray light rejection. The stray light is produced by solar disk radiation which is several order of magnitude brighter than the coronal radiation in both visible and UV. The solar disk radiation enters the instrument through the external aperture and stray light is produced by diffraction off the edges of the apertures and of the optical components, non-specular reflection off the mirror surfaces, and scattering off the mechanical structure.
In order to minimize the specular scattering off the mechanical structure of the light scattered by the edges of the external occulter, a system of 6 baffles has been designed (see figure 8). Their optical configuration has been optimized by several optical simulations, performed with

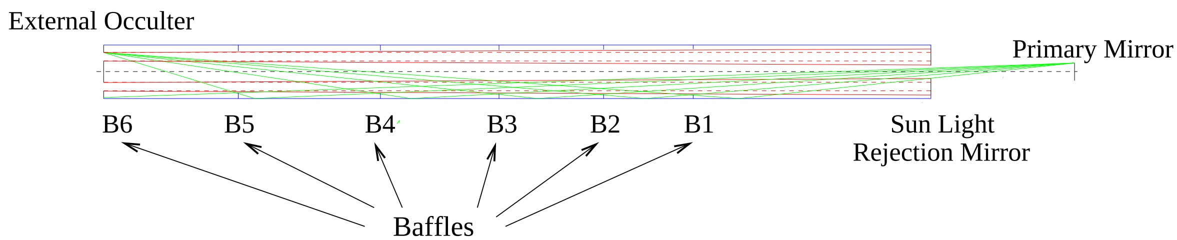


Figure 8: *Baffle system configuration for the HERSCHEL coronagraphs.*

Zemax 9.1 non-sequential surface ray tracing. A further set of simulations has been performed to determine the best coating for the mechanical parts of the coronagraph, in order to minimize the quantity of reflected stray light.
The light diffracted off the edges of the external occulter and non-specularly reflected by the mirror surfaces is the major source of stray light at all wavelengths: this light cannot be removed by additional stops because it follows the same path of the coronal light, and it has to be evaluated, to assure that it constitutes a negligible contribute.
In order to estimate the stray light level on the focal plane, a theoretical computation has been performed, using an Interactive Data Language (IDL) code (Landini 2002) (Romoli et al. 2001).

3.2.2. Optical characterizations

Polarimetry The XUVLab team has developed and constructed a single reflection linear polarization analyzer, and selected, after laboratory tests, the best reflection plate material and incidence angle for the spectral region 90÷125 nm (Corti 2001; Corti and Romoli 2001) (see figure 9).
The choice of this spectral window is related to the development of an UV polarimeter to exploit

Optical simulation Summary	
EUSO	Optimization of the optical adapter. Evaluation of the stray light impact on the focal plane.
HERSCHEL	Optimization of the baffles optical configuration. Selection of the best coating for the mechanical parts. IDL code to estimate stray light level on the focal plane.

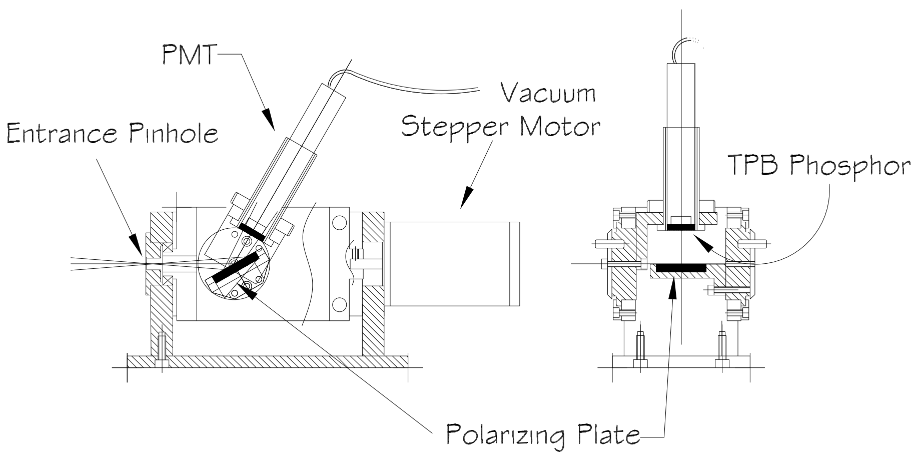


Figure 9: *The UV linear polarization analyzer of the XUVLab.*

the linear polarization modifications induced by the Hanle effect to retrieve the magnetic field vector of the extended solar corona, in particular for the MIDEX/Advanced Spectroscopic and Coronagraphic Explorer (ASCE) NASA project (see section 3.3.1).
The material and the incidence angle selection has been performed in the XUVLab for several different materials, selected in advance on the basis of the literature optical constants (Palik 1985; Palik 1991). The comparison of different material performances (A1) can only be done on relative grounds, due to the lack of knowledge on the linear polarization degree of the incident radiation and on the material reflectivity.
To overcome this problem a set of polarization measurements has been performed at the European Laboratory for Non Linear Spectroscopy (LENS), with a high-order harmonic laser beam. In fact, the laser radiation is fully linearly polarized allowing us to measure the absolute reflectivities, and therefore, to calibrate the XUVLab polarization analyzer. The data analysis is now in progress.
Once the polarization analyzer is calibrated, it has several applications. It will be possible to measure the polarimetric characteristics of several devices such as gratings, mirrors, and other optical components.

Optical characterizations Summary	
Material selection	Angle selection with measurements at XUVLab. Material selection with polarimetric measurements at LENS with 100%. linearly polarized source.

3.3. Space projects

The XUVLab activity includes the partecipation to several solar space mission in collaboration with italian and foreign institutions.
The XUVLab involvement in solar physics space missions originates from the primary role DASS still has in the SOHO (SOlar and Heliospheric Observatory) mission, both in the SOHO/-UVCS (Ultraviolet Coronagraph Spectrometer) data analysis and in the SOHO/UVCS in-flight instrument calibration (A6; A3). In addition the XUVLab team is collaborating with several INFN institutes in Italy in the EUSO (Extreme Universe Space Observatory) project.

3.3.1. ASCE

The Advanced Spectroscopic and Coronagraphic Explorer (ASCE) mission (http://cfa-www.-harvard.edu/asce/) was proposed for the first time to the NASA/MIDEX (Medium Class Explorers and Missions) in 1998 and was selected for Phase A study (Gardner et al. 1999), and it has been proposed again to the NASA/MIDEX (October 2001) and selected (April 2002) for Phase A, with some major updates and modifications (C3).
In both proposals, the XUVLab responsibility is the design, the procurement and the characterization of the EUV polarimeter (EUVP) assembly that belongs to the EUV polarimetric path of ASCE (see figure 10).
The EUV Polarimeter (T3) is designed to measure the linearly polarized brightness and the orientation of the polarization vector of the EUV lines from the hydrogen Lyman continuum to Lyα in the outer solar corona ($r > 1.2\ R_\odot$). The major objective of the EUV Polarimeter is the determination of the magnetic field intensity in the outer corona through the measurement of the Hanle effect, that produces depolarization and rotation of the polarization vector in the HI lines (Lyα, Lyβ, and Lyγ) (Fineschi et al. 1999). The secondary objective is the measurement of the polarization state of the atomic and ion lines (among the brightest the OVI lines). The polarization of the spectral lines gives an additional piece of information for the understanding of the solar wind velocity field, and the ion kinetic velocity distribution (C2). This represents the first attempt to measure the polarization state of spectral lines in the outer corona. Since no transmission polarizers are available in the $90\div130$ nm spectral range, a single reflecting surface placed at about the pseudo-Brewster angle with respect to the incidence beam will perform the best in terms of efficiency and polarization properties.
The research activity carried on by the XUVLab was the characterization of the polarizing properties of a selected number of material which best perform as reflecting polarization analyzers (Corti 2001 - see section 3.2.1). Recently, the polarizing properties of a limited number of materials have been measured with a fully linear polarized source (high order harmonics laser),

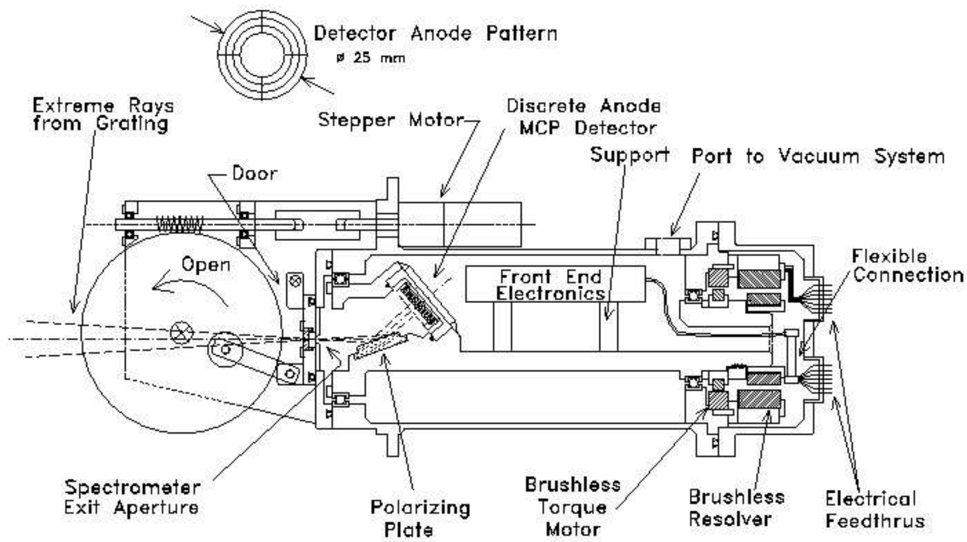


Figure 10: *The UV linear polarization analyzer of ASCE.*

at the LENS laboratory, to achieve an absolute characterization of the XUVLab polarization analyzer (see section 3.2.2).
The XUVLab is also involved in the definition and testing of the EUV polarimeter MCP detector in collaboration with the Istituto di Fisica Cosmica, CNR, Milano (Pace et al. 2000).
Finally, the XUVLab is responsible for the italian segment of the ASCE experiment and is coordinating the industrial activity that involves Galileo Avionica (for mechanics manufacturing and testing), Laben SpA (for front-end and remote electronics), and Photek Ltd. (for detector supply).

ASCE Summary	
Optical design	Polarization analyzer laboratory model calibration.
Detector	Defi nition and testing of the MCP detector.
General Organization	Phase A documentation. PIship of the italian contribution. Industrial activity coordination (Galileo Avionica, Laben, Photek).

3.3.2. SPECTRE

The Solar Dynamics Observatory (SDO) is the first Space Weather Research Network mission to be selected within the Living With a Star program of the NASA. The primary goal of SDO is

to determine how the Sun drives space weather and global change, and to understand how and why the Sun varies.
The scientific payload of SDO includes: the Helioseismic and Magnetic Imager (HMI), that will extend the capabilities of the SOHO/MDI (Scherrer et al. 1995) instrument, and will be able to determine vector magnetograms; the Extreme Ultraviolet Variability Experiment (EVE), that will measure the EUV solar irradiance with unprecedented spectral resolution, temporal cadence and precision; the Solar Heliospheric Activiy Research and Prediction Program (SHARPP), that will provide full-disk coverage at high spatial and temporal resolution, imaging simultaneously in several ultraviolet (UV) and Extreme-Ultraviolet (EUV) bandpasses, expanding the capabilitites of SOHO/EIT (Delaboudinière et al. 1995) and TRACE (Wolfson et. al 1997).
SHARPP is a set of two instruments: the Atmospheric Imaging Assembly (AIA) and the white light (Kontinuerlich-corona) Coronagraph (KCOR). The primary goals of AIA and KCOR are to characterize the dynamical evolution of the solar plasma from the chromosphere to the corona, and to follow the connection of plasma dynamics with magnetic activity throughout the solar atmosphere. The SHARPP/AIA consists of 7 telescopes imaging the following bandpasses: HI Lyα 121.6 nm , HeII Lyα 30.4 nm , OV 62.9 nm, NeVII 46.5 nm, FeXII 19.5 nm (includes FeXXIV 19.2 nm), FeXV 28.4 nm and FeXVI 33.5 nm. The telescopes are grouped by instrumental approach:

- Magritte Filtergraphs: five multilayer "EUV channels", with bandpasses ranging from 19.5 nm to 50.0 nm and one HI Lyα channel;

- SPECTRE Spectroheliograph: one soft EUV channel OV at 63.97 nm.

The SPECTRE (SPECtroheliograph for the Transition Region) program is a collaboration among the University of Firenze, Padova, Pavia and the Astronomical Observatory of Torino (OATo) in Italy; the Naval Research Laboratory (NRL) in the USA; the Max Plank Institut für Aeronomie (MPAe) of Lindau in Germany; the Centre Spatial de Liège (CSL) in Belgium. The SPECTRE principal investigator is Prof. Ester Antonucci (OATo).
The SPECTRE is a zero-dispersion spectroheliograph, optimized for imaging the soft EUV 62.97 nm OV line; its optical design consists of two spectrographs with opposite dispersion (see figure 11). The XUVLab will be responsible for the optimization of the optical design, including the stray light characterization, and for the laboratory testing of the optical components of SPECTRE.

SPECTRE Summary	
Optical design	Optimization of the optical design (in progress). Estimate of the stray light level on the focal plane (in progress).

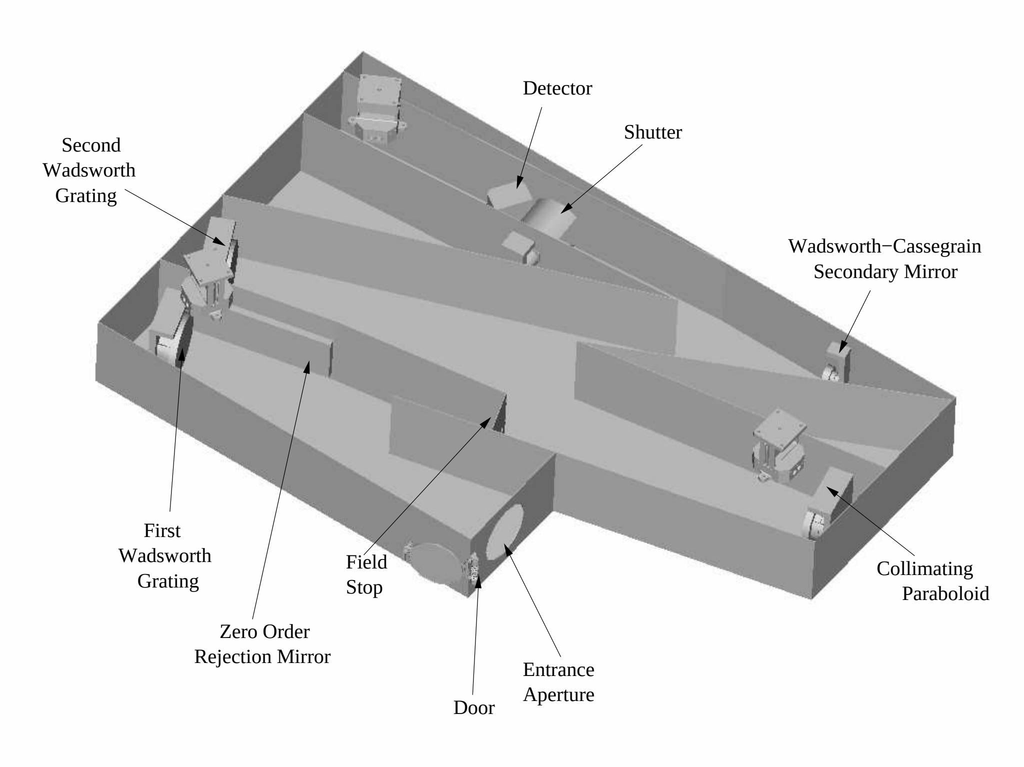


Figure 11: *Accomodation of the opto-mechanical elements on SPECTRE.*

3.3.3. HERSCHEL

The Helium Resonant Scattering in the Corona and Heliosphere (HERSCHEL) program is a collaboration among NASA and Naval Research Laboratory (NRL) in the USA; University of Firenze, Padova, Pavia and the Astronomical Observatory of Torino (OATo) in Italy; University of Paris in France. The principal investigators are Dr. Daniel Moses and Prof. Ester Antonucci. It has been proposed within Living With a Star (LWS) of NASA.
Helium, the second largest contributor to the density of coronal plasma, is important for the dynamics of the solar wind, and it may act as a regulator to maintain a nearly constant solar wind mass flux. Despite this crucial role, there is a lack of observations of Helium in the corona.
The HERSCHEL program will investigate the slow and fast solar wind, determine the helium distribution and abundance in the corona, and test solar wind acceleration models, by obtaining simultaneous observations of the electron, proton and helium solar coronae. Moreover HERSCHEL will establish proof-of-principle for the Ultra-Violet Coronagraph (UVC), which is in the ESA Solar Orbiter Mission baseline. HERSCHEL is a sub-orbital mission, composed of a telescope similar to SOHO/EIT (Delaboudinière et al. 1995) and two UVC-like coronagraphs (UVCI, Ultraviolet and Visible-light Coronal Imager) (A5; C1); figure 12 shows the instrument layout inside the sounding rocket. The italian consortium is responsible for the UVCI coronagraphs. The UVCIs image the solar corona from 1.4 $R_\odot$ to 4 $R_\odot$. One coronagraph is optimized

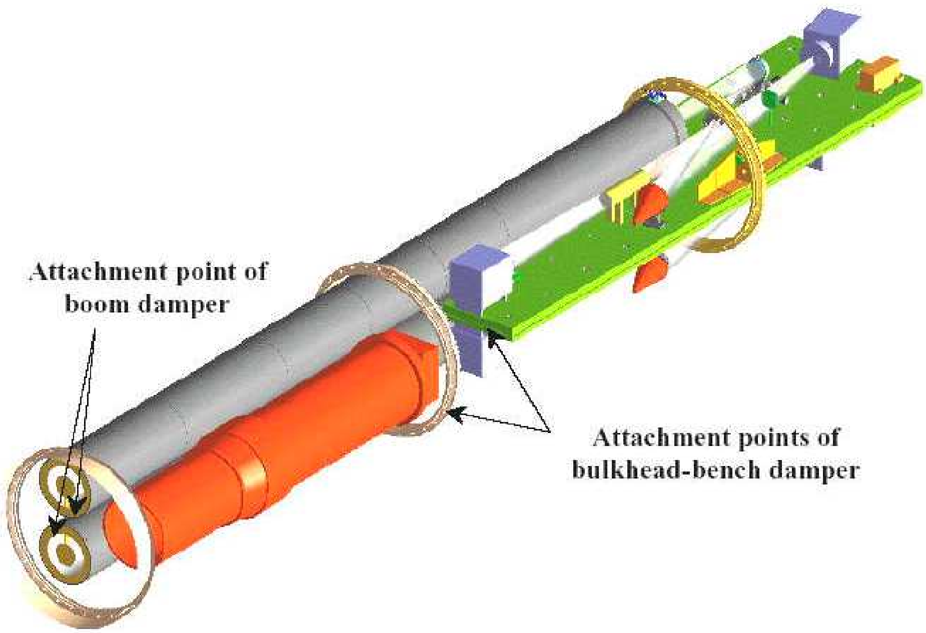


Figure 12: *Instrument layout inside the sounding rocket for the HERSCHEL mission.*

to image the HI Lyα 121.6 nm corona and one for the HeII Lyα 30.4 nm corona. They both have a visible light channel, to misure coronal radiation linear polarization.
The most stringent requirement on a coronagraph is the stray light rejection, and the novelty of the UVCI all-reflecting optical design, which is the first UV coronagraph to image the full corona at once, has made necessary a thorough stray light characterization of the coronagraph.
The XUVLab is responsible for the procurement of the optical component necessary for the stray light rejection and for the procurement of the visible-light CCD detectors (see section 3.1.2). In collaboration with OATo, it has been carried out a thorough analysis on alignment and assembly tolerances of the optical components, and a tolerance matrix has been compiled. The optical design has been optimized to reduce stray light to the lowest level: new optic components have been designed, as baffles and multiple occulters; in addition it has been estimated the stray light level on the focal plane (see section 3.2.1). These results have been achieved by Federico Landini during his Doctor degree thesis (Landini 2002).
The non-sequential mode of the ray tracing software Zemax 9.1 has been used to perform several simulations, to adjuste the optical configuration of the baffles, and to determine the most convenient shape for the external occulter back surface.
The alignment and assembly tolerances are essential to the industry responsible for the mechanical realization of the project; through a complex geometrical analysis on the reciprocal influence of the optical components positions, a table of angular and spatial tolerances of every optical component has been compiled.
A theoretical study of light diffraction from the coronagraph aperture and of the non-specular scattering off mirror surfaces has been carried out; a simulation algorithm has been developed

using the Interactive Data Language (IDL). The obtained results show that the stray light level is lower than the expected coronal signal at every wavelength of interest.

HERSCHEL Summary	
Optical design	Design of new components to maximize stray light rejection. Alignment and assembly tolerances analysis. Theoretical estimate of stray light level on the focal plane.
Visible-light CCD camera	CCD controller. Camera head and proximity electronics. Signal processing electronics.

3.3.4. EUSO

The Extreme Universe Space Observatory (EUSO) project (EUSO 2000; Catalano et al. 2001) is devoted to the detection of the very high-energy cosmic rays (E $> 10^{20}$eV), that is one of the most interesting and controversial problems in Astrophysics.
These cosmic rays can be observed by means of the giant showers they produce interacting with the Earth atmosphere.
The flux of these cosmic rays is very low ($\sim$1 event km^{-2}sr^{-1}century^{-1} estimated for a total of about twenty events observed so far) and sophisticated and complex detectors are therefore required to study them.
The observational technique consists of the detection of the nitrogen fluorescence light produced by particles showering in the Earth atmosphere as well as the diffuse reflection of the Cerenkov light at the Earth surface.
The fluorescence emission permits to determine the shower evolution in the atmosphere, to measure its energy and to determine the direction of the primary cosmic ray.
The detector must be equipped with an optical system with a large field of view to be able to observe a mass of atmosphere as large as possible.
It must have a good sensitivity to be able to detect also the less energetic showers and it must be fast enough to determine the direction of the primary cosmic ray.
The "Phase A" study has started in October 2001 and its completion is scheduled for September 2003.
During phase A, the XUVLab group, included in the EUSO INFN Firenze team, is engaged in studying some aspects related to the EUSO focal plane detectors, Multi Anode Photomultiplier Tubes (MAPMT, by Hamamatsu Corp.), and, in particular, related to the *microcell* which consists of the mechanical and electrical assembly of four detectors. This activity is in collaboration with the INFN Genova team and with the RIKEN Institute in Tokyo, Japan.
Preliminary measurements of the angular dependence of the 64-channel MAPMT response have been performed at the XUVLab (T2; C5) in a photon counting regime, using UV and visible

light sources. Afterwards, a specific instrumentation setup has been arranged to carry out electrical and/or optical characterisations of optics, optical materials and MAPMTs in the UV range of interest (300-400 nm).

This new setup allows a multi-channel readout (up to 32, presently), more degrees of freedom (2 translations and 1 rotation) for detector and light source alignment, and the arrangement of a nitrogen laser source to study the system at the same wavelength of mission operations.

Besides these activities, the XUVLab has investigated the performance of UV filters for EUSO (T1), based on the data reported in literature and on optical computer simulations. Taking into account the wide field of view of EUSO, several filter glasses have been analysed, because of the spectral features of the fluorescence light emitted by atmospheric nitrogen, the spectral distribution of the nightglow, and the spectral response of the MAPMT. This concept study has pointed out that BG3 and UG5 filter glasses from Schott and the U330 filter glass from Hoya Corp. are suitable candidates for the EUSO application; the mass impact and the mechanical arrangement of this filters has been studied in different configurations. Presently, solutions for the EUSO UV filter, matching the instrument requirements and the optical and mechanical constraints are still under study.

Furthermore, the XUVLab group has studied, in collaboration with the National Institute of Applied Optics (INOA), several solutions to define the design of the optical adapters in order to improve the collection efficiency of the EUSO detectors. Firstly, hemispherical lenses have been optimised to be coupled to the 64-channel photomultiplier, but the efficiency is still low. Therefore, the Winston cone have been investigated and the efficiency has been improved (see section 3.2.1).

The last solution is under evaluation and consists of a special light collector coupled to an electrostatic focusing photomultiplier.

EUSO Summary	
Optical design	Concept study of UV fi lters and selection of 3 candidates among fi lter glasses.
Detector	Preliminary measurements of the angular dependence of the UV response.
Instrumentation	Setting up a new electro-optical characterization facility.

4. Educational and training activities

The XUVLab is an academic research center. Therefore, educational and training activities are one of the main targets. The know-how of the XUVLab team is in the field of technologies for space- and ground-based astrophysics: these activities contribute to further spread this know-how among students and staff through seminars, lectures, short courses for professional advancements, thesis, Ph.D. thesis. Fellowship have been granted to graduated and post-doc students to carry out studies on detectors and space instrumentation. The XUVLab has also employed technicians and associate researcher and still some of them are part of the staff. They contribute to the development of experimental activities, but they also acquire substantial expertise on instrumentation, equipments, characterization procedures, electronics, and optics.

A list of the thesis completed at the XUVLab in 2002 is hereafter reported:

- Antonio De Sio, "Analisi funzionale di dispositivi a diamante per la rivelazione di fotoni XUV per applicazioni astrofisiche", April 2002.
- Federico Landini, "Analisi della luce diffusa nel coronografo UVCI di HERSCHEL", September 2002.
- Alessandro Gherardi, "Elettronica di controllo per la camera CCD del canale polarimetrico di HERSCHEL", December 2002.

5. Funded projects

The XUVLab activities have been supported by national institutions and the list of the funded projects follows:

- "Matrici ibride di pixel in tecnologia CMOS su silicio e film sottile di diamante sintetico per la rivelazione d'immagini nell'X-UV", funds from the University of Firenze.
- "Progettazione ottica e analisi di stray light per esperimenti HERSCHEL e EUSO", funds from the University of Firenze.
- "Sviluppo e caratterizzazione di un polarimetro EUV a riflessione per l'Astronomia", funds from the University of Firenze.
- "Camera CCD di nuova generazione a conteggio di fotoni con i sensori innovativi Marconi L3CCD, per applicazioni all'osservazione di sorgenti astronomiche deboli e rapidamente variabili", funds from the University of Firenze.
- "Ottiche di riflessione nel vacuum UV basate su diamante CVD per sistemi ottici in applicazioni spaziali", A.S.I. contract no. I/R/125/01.
- "Low power visible blind and radiation hard diamond UV imagers for future space applications", A.S.I. contract no. I/R/125/01.

- "Advanced Solar Coronagraph Explorer", A.S.I. contract no. I/R/125/01.
- "Airwatch *R&D*", I.N.F.N. contract.
- "Extreme Universe Space Observatory", A.S.I. contract.

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