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SCOUT: Small Chamber for Optical Uv Tests

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***Abstract* — SCOUT is the acronym of the new facility developed within the XUVLab laboratory of the Department of Physics and Astronomy of the University of Florence. SCOUT stands for "Small Chamber for Optical UV Tests" and has been designed to perform practical and fast measurements for those experiments requiring an evacuated environment. SCOUT has been thought, designed and manufactured by paying a particular attention to its flexibility and adaptability. The functionality and the capabilities of SCOUT have been recently tested in a measurement campaign to characterize an innovative wire-grid polarizer optimized to work in transmission in the UV band.**

This paper provides a description of the overall manufactured system and its performance and shows the additional resources available at the XUVLab laboratory in Florence that make SCOUT exploitable by whatever compact (within 1 m) optical experiment that investigates the UV band of the spectrum.

***Index Terms* — Optical tests, vacuum test facility, ultraviolet band, optical facilities.**

I. Introduction

Science generally advances in parallel to the technological improvement of the investigating tool scientist use to conduct their experiments. Since 1998 the XUVLab laboratory [1], within the Department of Physics and Astronomy of the University of Firenze, works on the design, development and characterization of new technologies for space and earth-based instrumentation. The laboratory's activity mainly focuses on the development of optical and electronic systems working in the vacuum UV and visible band of the electromagnetic spectrum. Through the years the XUVLab has contributed to several international experiments, in particular oriented to the observation of the solar corona and to the measurement of its polarized brightness (for instance, SOHO/UVCS [2], ASCE [3], HERSCHEL rocket mission [4,5,6]).

In the continuous effort of improving the current technologies and studying innovative solutions for future experiments, we are carrying on a project for the development of an UV polarizer based on nanowires. The only polarizer realized for space applications and operating in the UV band used a beam splitting [7] making the optical design of the overall instrument more complex. A polarizer working in transmission based on dichroic materials or using wire grid structures, would greatly ease the design of the instrument.

Unfortunately there are not dichroic materials working in the UV band. Actually, one of the main challenges that UV researchers face is the lack of UV-transparent materials, particularly below 150 nm, where only some fluorides, as the MgF2, show acceptable performance. Moreover wire grid polarizers have in general higher transmittances than dichroic materials and cover a wider range of the electromagnetic spectrum. The structure of parallel wires constituting a wire grid polarizer has to have a pitch at least of the same order of magnitude (actually 1/3 [8]) than the wavelength we are interested in studying. For the UV band this means we need structures of some tens of nanometers. Such a tiny pitch is achievable by means of nanotechnologies presently available [9]. Such a polarizer, combined with piezo-actuated MgF2 dichroic crystal, may allow the manufacturing of a very compact and light polarimeter, suitable for space missions.

The first step in getting the final goal of our long-term investigation has been the design and set-up of a suitable experimental structure in order to characterize the polarizer we wanted to realize. This paper is dedicated to the description of such a laboratory facility that is called SCOUT (Small Chamber for Optical UV Tests).

In particular, section II describes the requirements that drove the facility design, section III and IV provide an overview of the obtained structure and of the instrumentation that can be used with it. Finally section V gives an example of an experiment carried on using the features of the developed facility. Even though SCOUT has been thought and designed in order to perform characterization measurements on a polarizing plate, it has been manufactured by paying a particular attention to its flexibility. This allows SCOUT to be re-used for whatever UV optical characterization, in particular those that requires compactness and velocity of execution.

II. Design Requirements

SCOUT has been designed almost from scratch using the structure of an old vacuum chamber. Although we had an immediate application in mind, we tried to develop a facility as versatile as possible while offering a good level of customization, enabling the use of optional parts and interfaces that extend the functionalities of the system.

One of the main driving requirements were the compactness of the entire facility in order to speed up the chamber evacuation and get an acceptable vacuum level in a reasonable time frame. This aspect is fundamental when the tests procedure requires the aperture of the chamber many times (for example to properly align different configurations of the same optical system or change a sample under investigation).

In order to accommodate the necessary equipment inside the chamber, an optical bench was essential to provide a stable and stiff reference plane. A dedicated mechanics must also be foreseen to make the chamber opening and closing operations repeatable and stable.

Finally, the chamber should be equipped with a proper number of interfaces in order to accommodate the several auxiliary devices needed for vacuum applications: pressure gauges, evacuation circuits, electrical feed-through, interfaces for external instruments like light sources, detectors and acquiring systems.

III. Mechanical Structure

SCOUT was manufactured according to the constraints and to the “desiderata” explained in section II. This section describes the technical detail of its mechanical structure and the vacuum circuit.

The 400 mm wide cylindrical steel tube that constitutes the lateral walls of the chamber is built by two sections that can be composed to change the longitudinal length of SCOUT (300, 600 and 900 mm) to optimize the evacuation time according to the experimental equipment that must be installed inside. The vertical flange that closes the tube from one side (see Figure 1) is fixed to a removable optical bench able to host a confined optical system. Both the steel tube and its closing flange can be moved on a pair of shared rails enabling the possibility of fixing one or the other part of the chamber depending on the experimental needs. The rail guarantees also repeatability in all the actions that involve chamber translations. The other side of the chamber has a modular cap that offers 4 different-sized mechanical interfaces to connect auxiliary instrumentation. The lateral wall of the chamber has 4 further flanges (3x65 mm, 1x150 mm) that have been used to connect the external vacuum circuit, two full-range pressure gauges and provide electrical connections. A 150-mm wide electrical feed-through in fact provides 3 D9 and 5 SMA and a high voltage SMC connector.

A very stable table was designed to support the chamber. It was manufactured with Bosch Rexroth® modular profiles. The stability is required since the table must be the reference for an optical set-up and the support for a heavy system that is continuously connected to working vacuum pumps.

SCOUT vacuum system is composed by a primary pump and by a Turbo-molecular pump (TMP) for the high vacuum. A classical cross-over configuration has been adopted in order to gain in vacuum conductance and keep a safe approach in case of turbo molecular pump failures. We equipped SCOUT with

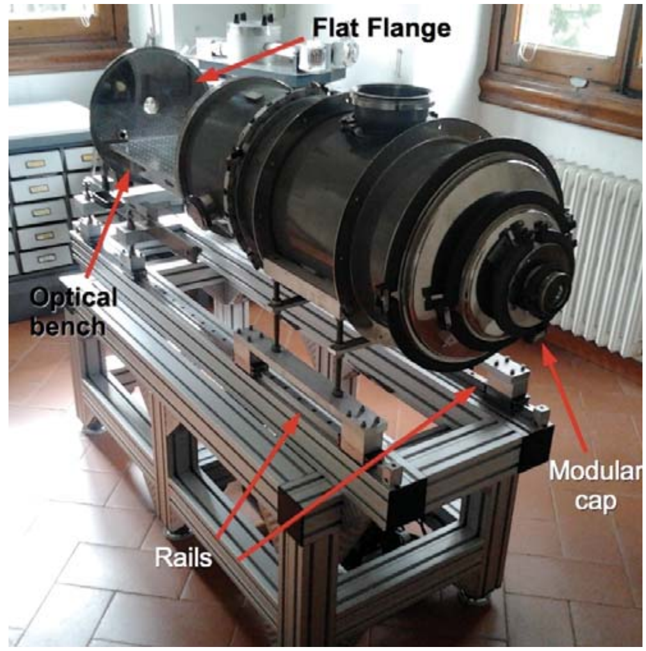

Figure 1: An overall view of SCOUT. The facility is opened to make the internal optical bench visible.

a butterfly gate valve mounted on the top to the TMP in order to isolate the chamber from the pumping circuit during the reopening procedure so speeding up the venting operation. The obtained system enable to reach the vacuum regime needed for the tests ($1 \div 2 \times 10$-4 mbar) within half a hour and can be brought back at air pressure in less then 10 minutes.

In order to keep the whole assembly as compact as possible, we decided to host the primary pump within the table built to support the chamber. In the top part of the table, directly in contact with the vacuum chamber, the middle transverse structural profile is missing, in order to have some clearance and keep the vacuum hose from the primary pump attached to the chamber even when the mobile part of the chamber is displaced apart from the fixed one.

IV. Optical and Electronic equipment

SCOUT has some electronic equipment to provide additional features useful to control and manage the experimental instrumentation. Beyond the capability of measuring the internal pressure of the vacuum chamber, a couple of PT100 probes enable the temperature monitoring from outside. Peltier cells can be used to cool or heat small part of the experiment set-up and cryocooler could be used too (in the next future).

A couple of vacuum compatible micrometric translation stages (with a stroke respectively of 75 and 200 mm) can be mounted to provide x-y movement capability and can be interfaced to an additional rotation stage if needed. These vacuum motors enable a high resolution positioning, 0.5 μm, and repeatability better than 10 μm and can be used to change the setup configuration of an experiment maintaining the chamber closed and preserving the vacuum condition.

The XUVLab is then equipped with several instruments that can be easily interfaced to SCOUT in order to conduct a wide range of investigation involving the UV and visible band.

Several source are available (hollow cathode, spectral lamps) that can be connected to two monochromators to cover the wavelength range 30 -1100 nm.

A calibrated Photodiode (PD), enhanced for the UV detection, can be used for calibration purposes in the range 5-254 nm. A series of PhotoTubes (PT) and PhotoMultiplier Tubes (PMT) constitute the detecting system to monitor the UV radiation at very low intensity. Thanks to the use of a high voltage Power Supply and of a “Photon Counting Unit” we can monitor also extremely low light flux.

All the auxiliary devices needed to control an experiment could be managed directly from a PC that collects all the data incoming from the probes, motors and detectors accommodated inside the chamber and that can be remotely controlled. A dedicated Labview (by National Instruments) interface was generated in order to manage, on a single computer screen, all the interactions with the devices.

V. SCOUT AT WORK

The functionality and the capabilities of SCOUT have been extensively tested in the measurement campaign to characterize the wire-grid polarizer (WGP) optimized to work in transmission in the UV band that is currently under development within our laboratory.

Several nominally identical nano-wire grid polarizers have been produced, in order to compare them and check whether the manufacturing procedure is reliable and repeatable. A first set of nano-wire with a pitch of 100 nm (suitable to polarize light at 250÷300 nm) has been realized and their characterization has been carried out using a set-up accommodated inside SCOUT.

The flat flange of the chamber (see Figure 2) was interfaced to a Rowland circle 0.5 m monochromator that selected the operating wavelength band of a D2 standard source lamp. A vignetting diaphragm was placed after the monochromator focus, in order to limit the system pupil, since the nano-wire grid polarizer plate surface is a few square millimeters.

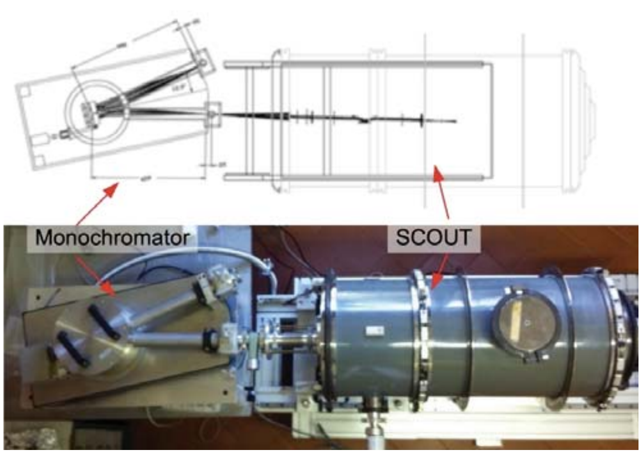

Figure 2: Top view of SCOUT. Top: superposition of the Zemax(by Radiant Zemax, LLC) ray tracing simulation and the CAD design of the whole system (monochromator plus SCOUT) used for the polarizer characterization. Bottom: the actual implementation.

A collimating lens in MgF2 was placed right after the vignetting diaphragm, in order to obtain a collimated beam. The lens is a double-convex with a diameter of 1” and a focal length of 452 mm.

The collimated beam is processed by a three reflections polarizer [10] (TRP) that provides the reference-polarized source used to illuminate and characterize the WGP. The TRP polarizes the beam by reflection at the Brewster angle from a MgF2 crystal, while keeping the axial direction of the impinging beam. The motorized rotation stage that SCOUT is equipped with, was used to change the roll angle of TRP thus allowing the selection of the desired direction of linear polarization.

A further lens was inserted at the end of the optical system, in order to focus the beam on the detector. It differs from the previous lens only in its focal length of 251 mm, giving an optical demagnification of 0.5.

We selected the R1463-P PMT by Hamamatsu as detecting photometer for the measurements. It is a head-on module with a spectral response range between 185 nm and 850 nm. The PMT was operated inside SCOUT in the so called anode grounded configuration. It was fed from outside by means of electronics vacuum feed-through connected to a high voltage power supply unit, a Stenford PS350, providing up to 5kV and 5mA of current. The output signal was brought through a shielded cable+feed-through connector to a Photon Counting Unit, C3866 Hamamatsu, and then passed to a digital counter, the HP53131A, that provided the number of photons per second that were impinging on the detector surface.

Since the position of the focal plane of the collimating lens moves along the optical axis when the wavelength of the illuminating beam is changed, the PMT was mounted on one of the vacuum translation stages in order to compensate this movement.

Finally, the calibrated PD, the IRD AXUV100, was mounted in a parallel optical path to monitor the stability of the source and distinguish the flux variation due to the source from that one caused by the modulation of the WGP. An overall view of the implemented setup is shown in Figure 3 whereas Figure 4 shows more in details the instrumentation mounted on the optical bench inside SCOUT.

The WGP characterization was then obtained measuring the radiation flux hitting the PMT photocathode at different rotation of the TRP (i.e. at different incoming polarization). When a complete rotation was obtained, we changed the monochromator setting in order to characterize the WGP at different wavelengths.

The overall acquisition procedure and the control of the entire equipment was automatized and controled by an external computer. The same PC was in charge to collect the data coming from the detectors, temperature probes, translation and rotational stages too.

Figure 2 shows a superposition (as seen from the top of the optical bench) of the Zemax (by Radiant Zemax, LLC) ray tracing simulation and the CAD design of the whole system

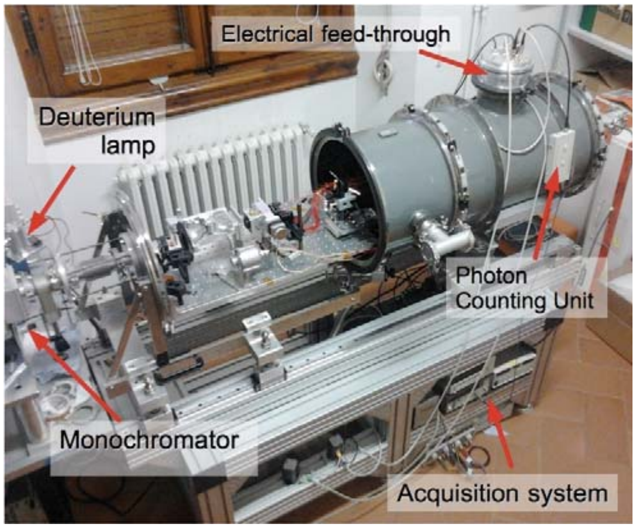

Figure 4: SCOUT during the measurement campaign.

(monochromator plus SCOUT) for the WGP characterization and the picture of the whole system from the same point of view.

VI. CONCLUSIONS

Due to its peculiar design, SCOUT is characterized by an accentuated flexibility that makes it suitable for a much wider range of UV applications than simply the one for which it has been thought. As an example, the guides system allows the movement of the flange that for the polarizer experiment must be taken fixed because attached to the monochromator.

Several auxiliary flanges provide a wide possibility to interface different devices, sources and instruments. One of the flanges closing the chamber is made by several modules that allow the integration of instruments with apertures of different diameters. An electrical feed-through, equipped with numerous kind of connections, is available too.

The relatively small internal volume of SCOUT allows to rapidly (roughly half a hour) reach the vacuum regime needed for the tests (1÷2×10-4 mbar), once the optics have been placed and aligned on the internal bench. This aspect resulted fundamental for the polarizer experiment sketched in this paper, since several tests had to be repeated in vacuum: for each nano-wire test plate the system had to be vented in order to place and align the optics, then it had to be evacuated again to perform the measurements. Furthermore, the whole SCOUT chamber is made by two smaller chambers attached together: one 300 mm long, the other 600 mm long. In case a reduced inner space is requested by successive experiments (the maximum length was used for the polarizer experiment), SCOUT can be configured with a shorter length, thus further reducing the time it takes to reach the desired vacuum regime.

In conclusion, SCOUT is suitable for optical prototype testing at sub-system level in the VUV, UV and visible wavelength ranges for polarization, efficiency (transmission and reflection), narrow-band spectroscopy characterizations and all the correlated applications.

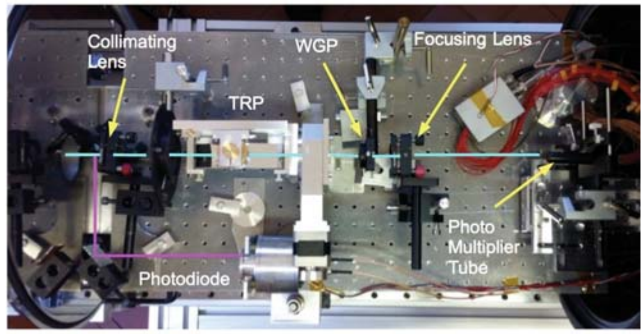

Figure 3: A top view of the setup accommodated on the SCOUT optical bench for the polarizer characterization. The optical path is superimposed in blue (main path) and in pink (parallel path). The main components of the setup are indicated as well.

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REFERENCES

[1] Chiuderi, C., Landini, M., Noci, G., Corti, G., Pace, E., Romoli, M., Baglioni, R., di Franco, S., Marcucci, G. and Sozzi, M., “XUVLAB: Project for an UV Laboratory at the University of Firenze”, ESASP 417, 263-266 (1998).

[2] Kohl, J. L., et al., “The Ultraviolet Coronagraph Spectrometer for the Solar and Heliospheric Observatory”, Sol. Ph. 162(1-2), 313-356 (1995).

[3] Gardner, et al., “Advanced Solar Coronal Explorer mission (ASCE)”, Proc. SPIE 3764, 134-146 (1999).

[4] Romoli M., et al, “The Ultraviolet and Visible-light Coronagraph of the HERSCHEL experiment”, Proc. Solar Wind Ten 679, 846-849 (2003).

[5] Fineschi, S., Antonucci, E., Romoli, M., Gardiol, D., Naletto, G., Giordano, S., Malvezzi, M., Da Deppo, V., Zangrilli, L. and Noci, G., “Ultraviolet and Visible-light Coronagraphic Imager (UVCI)”, Proc. SPIE 4853, 162-171, (2003).

[6] Pancrazzi, et al., “HERSCHEL/SCORE, imaging the solar corona in visible and EUV light: CCD camera characterization”, Anal. Bioanal. Chem. 397, p. 2033, (2010)

[7] Nordsieck, K. H., et al., “The Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE)”, Bulletin of the American Astronomical Society, Vol. 23, p.906, (03/1991)

[8] Wang J.J., et al., “High-performance, large area, deep ultraviolet to infrared polarizers based on 40 nm line/78 nm space nanowire grids”, Appl. Phys. Lett. 90, 061104 (2007)

[9] Pelletier, V., Asakawa, K., Wu, M., Adamson, D. H., Register, R. A. and Chaikin, P. M., “Aluminum nanowire polarizing grids: Fabrication and analysis”, Ap. Phys. Let. 88, ref. 211114, (2006).

[10] Hass, G. and Hunter, W. R., “Reflection polarizers for the vacuum ultraviolet using Al + MgF_2 mirrors and an MgF_2 plate”, Ap. Opt. 17(1), 76-82 (1978).