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M. G. Pelizzo, A. J. Corso, G. Santi, M. Uslenghi, M. Fiorini, et al.

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PLanet extreme Ultraviolet Spectrometer project

M.G. Pelizzo
Consiglio Nazionale delle Ricerche, Istituto di Elettronica, Ingegneria dell'Informazione e delle Telecomunicazioni, c/o UNIPD-DEI via Gradenigo 6B, 35128 Padova, Italy

A.J. Corso
Consiglio Nazionale delle Ricerche, Istituto di Fotonica e Nanotecnologie, via Trasea, 7, 35131 Padova, Italy

G. Santi
Università di Padova, Centro Interdipartimentale Studi e Attività Spaziali, viale Venezia, 35131 Padova, Italy

M. Uslenghi, M. Fiorini, S. Incorvaia, G. Toso
Istituto Nazionale di Astrofisica, Istituto di Astrofisica e Fisica Cosmica Milano, Via A. Corti 12, 20133 Milano, Italy

E. Fabbrica, M. Carminati, C. Fiorini
Politecnico di Milano, Dipartimento di Elettronica, Informazione e Bioingegneria, and INFN Sezione di Milano, Milano, Italy

G. Favaro, M. Bazzan, G. Maggioni
Università di Padova, Dipartimento di Fisica e Astronomia, via Marzolo 8, 35131 Padova, Italy

ABSTRACT

Spectroscopic observations in the far (FUV, 115-200 nm) and extreme (EUV, 40-115 nm) ultraviolet is of fundamental importance in solar physics, in the physics of interstellar medium, in the study of planetary exospheres. The PLUS project is focused on the development of a high-performance spectrograph for the observations of planetary exospheres in the 55-200 nm range. The instrument layout is based on a two channels (VUV/EUV) design. It will be characterized by improved detection limit, shorter observations integration time and unprecedented performance in terms of dynamic range. Such characteristics will be obtained thanks to the development and combination of two key technologies: high efficient optical components optimized for each channel and high resolution/dynamic range solar blind photon counting detectors. The photon counting detector will be based on a Micro-Channel Plate (MCP) coupled with an Application Specific Integrated Circuit (ASIC) read out system.

Keywords: ultraviolet, spectrometer, gratings, micro-channel plates, application specific integrated circuit

1. INTRODUCTION

Spectroscopic observations in the far and extreme ultraviolet (FUV/EUV) spectral region is of great interest in various scientific fields, such as in Solar Physics, in the physics of interstellar medium and in the planetary exospheres studies. The most recent and advanced planetary mission payloads include an FUV/EUV imaging spectrometer, such as Bepi-Colombo/PHEBUS [1], Juno/UVS [2], New Horizon/Alice [3], Venus Express/SPICAV [4], Europa/UVS [5]. FUV/EUV imaging spectrometry is natively the best technique to probe the exospheres (direct detection) and the

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highest-altitude atmospheres (through stellar occultation) of planets and satellites. It is particularly suitable to determine constituents, to study the atmosphere dynamics, to understand the formation mechanisms and the surface release processes. The most significant spectral features are in the 55 to 200 nm spectral range, where neutral atoms and relative ions (N, H, He, C, O, S, Na, K..), and hydrocarbons (CH_4, C_2H_2, C_2H_4, C_2H_6, HCN, HC_3N,…) can be detected [6-9]; possible presence of surface ice layers can be also identified thought the other spectral features (HO, H_2O, S_2O) [10,11]. This remote sensing technique is also particularly indicated to work in synergy with many in-situ measurements as it provides complementary and pivotal set of observations. Although in-situ observations give very precise measurements of the composition, chemistry, dynamics and evolution of a planetary atmosphere [12], they are spatially and temporally limited and unable to clearly detect some constituents due to instrumental limits or local contaminations [13-15]; conversely, FUV/EUV imaging spectrometry allows a great spatial coverage, a valuable temporal analysis and the concentration measurements of a broad set of constituents undetectable with in-situ techniques. In addition to exospheres and atmospheres studies, the FUV/EUV spectroscopy is a valuable technique to investigate auroras occurring in giant planets; in fact, the wavelength range from 50 to 200 nm covers all the important features related to the H_2 bands and the H Lyman series produced in auroras, as well as some important signatures of aurora-produced hydrocarbons [16, 17]. Moreover, observations of other ionized species signatures, combined with in-situ measurements of the magnetic field, allow to retrieve information on solar wind-magnetosphere-ionosphere interactions. Extending these benefits to other targets, EUV imaging spectroscopy is also suitable to study the composition of the giant planets ring systems, giving valuable information on the composition, structure and spatial dimensions [8, 18, 19].

Considering the future long-term space mission programs, many targets will require a mission whose payload includes an UV imager spectrograph. For instance, future missions on gas or ice giants planets will require imaging spectroscopy for a comprehensive study of the aurora footprints and polar magnetosphere as well as the characteristics of the upper atmosphere or exosphere of their satellites (Europa, Titan, Triton,…) [20, 21]. On the other hand, future missions on the inner planets will also resort to imaging spectroscopy for exosphere or ionosphere science [22].

Parameter	**EUV channel**	**FUV channel**
Grooves density (N)	2400 lines/mm	1600 lines/mm
Grating radius (R)	201.4 mm	215.0 mm
Incidence angle (α_2)	-14.1°	17.05°
Grating angle (α_{G2})	-11°	14°
Diffraction angle central wavelength $\lambda_{m2}(\beta_{m2})$	1.90°	-6.27°
Diffraction angle for $\lambda_{sup2}(\beta_{sup2})$	-2.56°	-2.36°
Diffraction angle for $\lambda_{inf2}(\beta_{inf2})$	6.39°	1.54°
Input arm (L_{A2})	201.4 mm	201.4 mm
Output arm (L_{B2}) at λ_{m2}	202 mm	230.4 mm
Grating center position (x_{C2}, y_{C2})	(201.1, 10.82) mm	(201.1, 10.82) mm
Detector center position (x_{D2}, y_{D2})	(196.9, 55.92) mm	(196.9, 55.92) mm
Detector angle (α_{D2})	18°	-23°
Slit width	200 µm	200 µm
Total pixel for the spectrum	950 pixels	945 pixels
Spectral resolution for a fulfilled slit (on the whole spectral range)	<0.5 nm	<0.7 nm

Table 1. Optical configuration parameters.

2. OPTICAL DESIGN AND COMPONENTS

Within the PLUS project, a novel dual channel FUV/EUV imaging spectrometer working in 55-200 nm spectral range will be developed with the intent of improving both the optics efficiency and dynamic range. A substantial improvement with respect to the conventional solution will be given by splitting the spectral range into two different channels, one working in the extreme ultraviolet (EUV, λ~55-120 nm) and the other one in the far ultraviolet (FUV, λ~115-200 nm). A compact FUV/EUV dual channel variable line-spaced (VLS) spectrometer has been designed. In order to improve the performances of the spectrometer, while simplify its scheme, a Harada configuration has been adopted; differently from PHEBUS on board of Bepi-Colombo [23], in this configuration the required aberrations correction is achieved with a specific out–of–Roland geometry, which further optimizes the aberration compensation making use of two spherical variable line-spaced gratings. The configuration parameters are reported in Tab.1, while the layout is shown in Fig.1, together with some simulation results. With this arrangment, each channel will be equipped with coatings having high efficiency in that restricted wavelength range (Fig.2).

Input parameters:

Pixel size (from the ASIC design): $x_{px} = 35\ \mu m$

Standard commercial gratings parameters: $L_G = 20$ mm
$n = 2400$ lines/mm
$R_G = 201.4$ mm

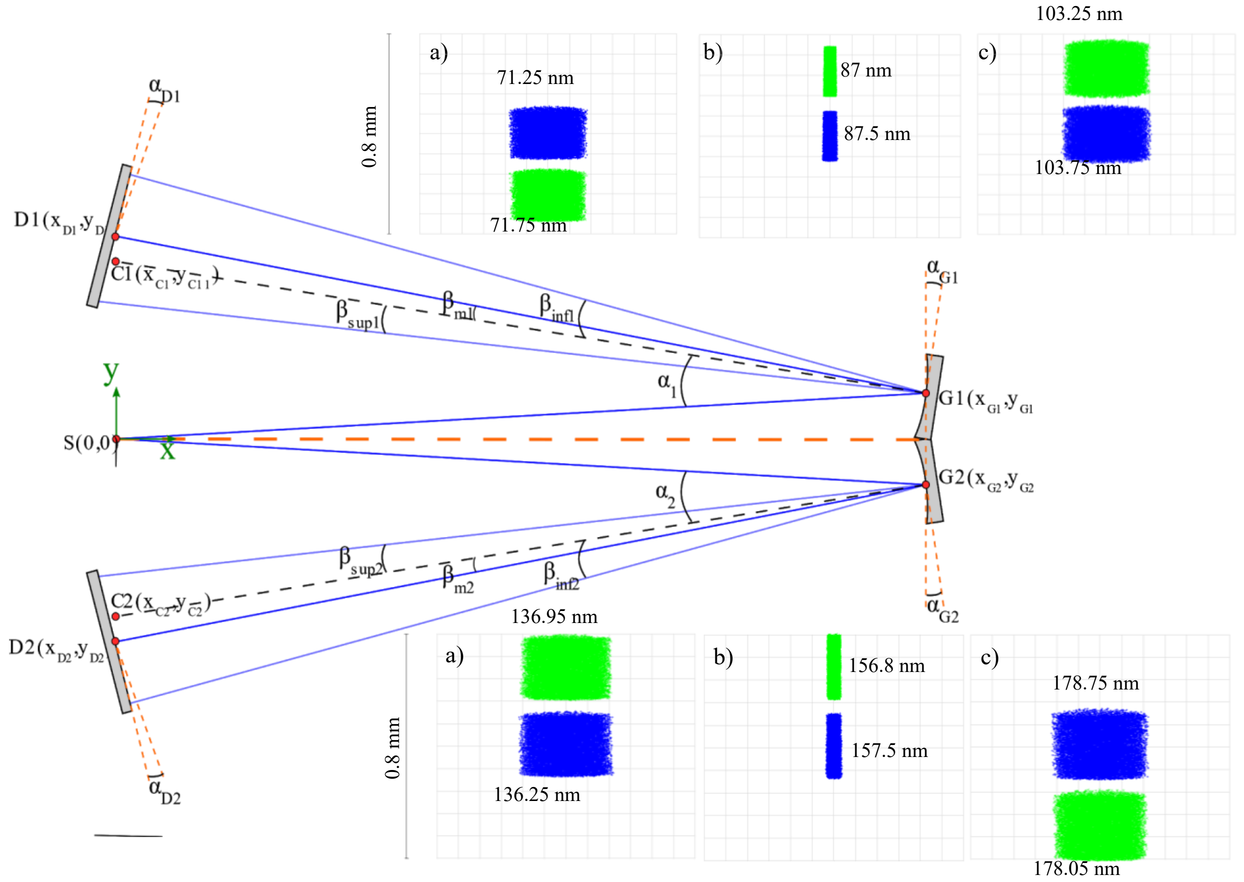
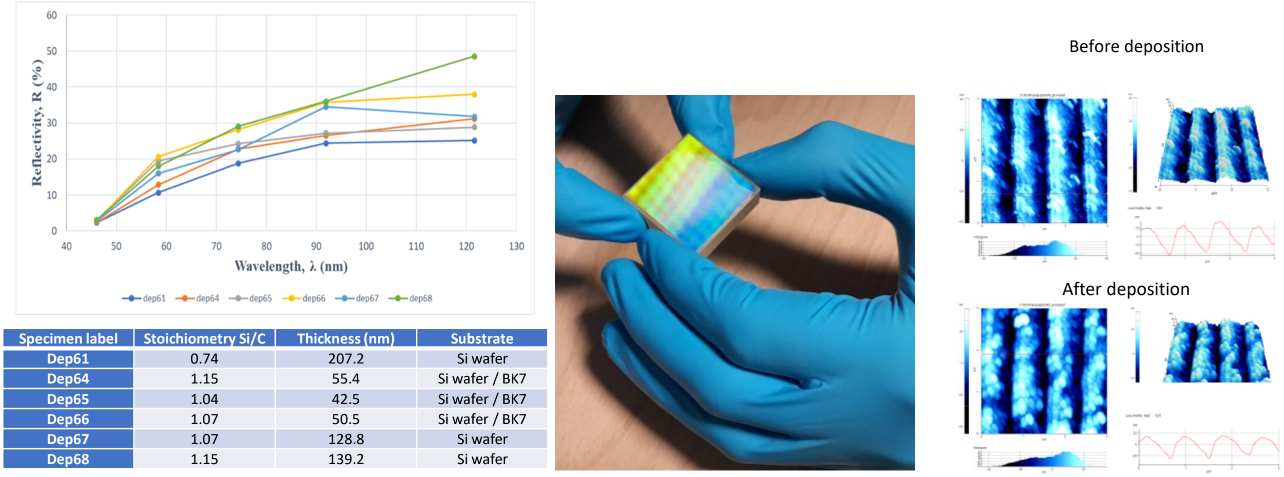


Fig.1 Dual channel optical design and simulations.



Specimen label	Stoichiometry Si/C	Thickness (nm)	Substrate
Dep61	0.74	207.2	Si wafer
Dep64	1.15	55.4	Si wafer / BK7
Dep65	1.04	42.5	Si wafer / BK7
Dep66	1.07	50.5	Si wafer / BK7
Dep67	1.07	128.8	Si wafer
Dep68	1.15	139.2	Si wafer

Fig.2 SiC coating on wafer substrate samples (left) and on a plane grating (right).

3. DETECTOR AND READOUT ANODE

A MCP detector based on a 2D anode array integrated into imaging Read Out Integrated Circuits (MIRA - MIcrochannel plate Readout ASIC), with photon counting capability on chip is under development. Such detector will provide higher dynamics and longer lifetime with respect to state of the art. A demonstrator of an ASIC is under fabrication. Each pixel contains an anode to collect the electrons emitted by the MCP, a low noise amplifier and filter to maximize the SNR, a comparator to recognize and count single photon events, logic to correct for charge sharing among pixels (CSCL) and two counters, which will form the counting matrix (Fig.3). Periphery circuitry allows setting the measurement parameters and readout of the serial digital data stream. The parallel architecture of the event recognition electronics will allow to support extremely high local dynamic range, with the goal of reaching the physical limit of the MCP. The 2D array of counters will allow building an on-chip accumulation matrix, in order not to limit the global dynamic range. Each pixel will host 2 counters (C#1 and C#2), at each time one will be used for counting photons and the other will be available to be readout, in order to achieve zero dead time. Each pixel in the array is scanned in a regular way; all pixels are readout within the 1s time (no event-driven logic).

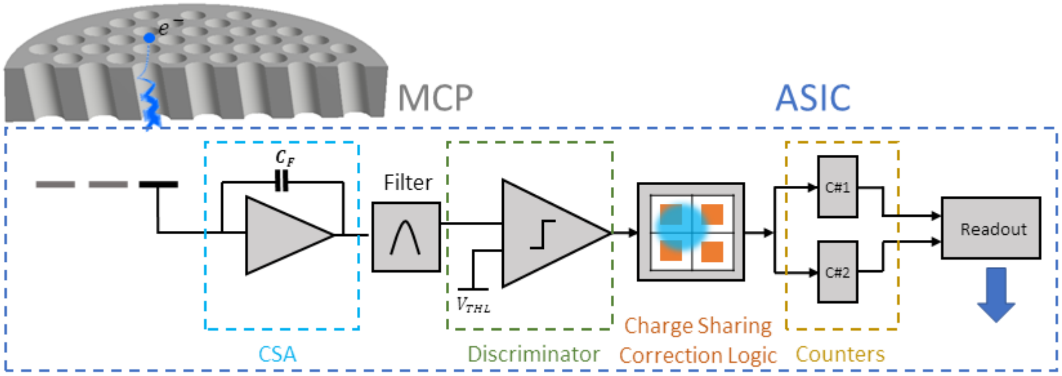


Fig.3 Detector architecture.

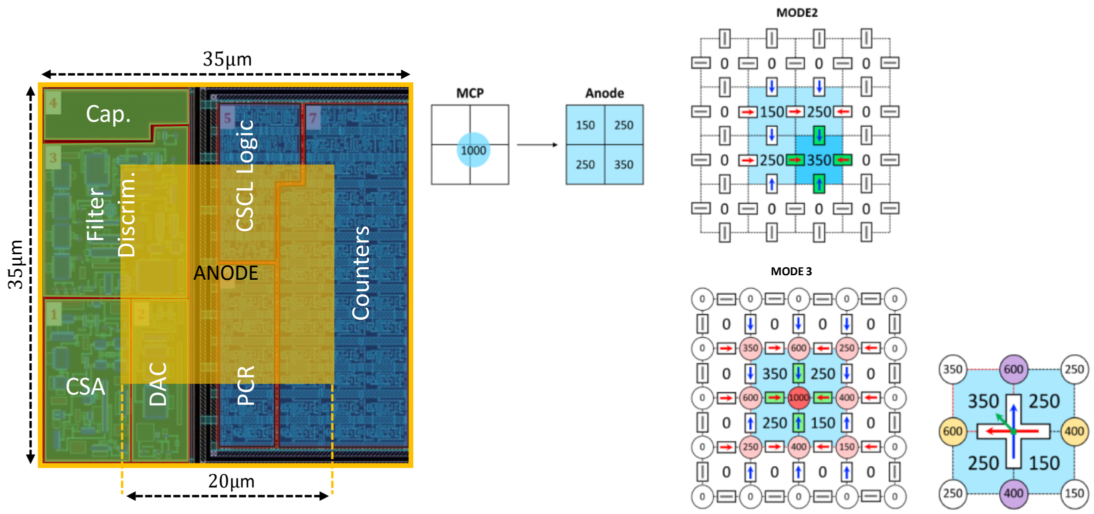


Fig.4 Pixel electronics and charge sharing logic.

Since the diameter of the electron cloud exiting from a Chevron type MCP is comparable with the pixel pitch of 35µm, the charge sharing effect occurs; this results in a degraded spatial resolution. The Charge Sharing Correction Logic identifies, then, the pixel with the most collected charge, avoiding fake hits and granting a pixel limited spatial resolution (Fig.4). The ASIC features three modalities of Charge Sharing Correction Logic: 1) Mode1, where the Pixel is configured in Single Pixel mode and the Charge Sharing Correction Logic is disabled; this modality is for testing purposes; 2) Mode2 where the Pixel is configured in Single Pixel mode and the Charge Sharing Correction Logic is enabled; 3) both vertical and horizontal comparisons are performed in Mode3, where the pixel is configured in Charge Summing mode and the Charge Sharing Correction Logic is enabled. The ASIC design of the prototype under fabrication is shown in Fig.5. It consists of a demo of 32 x 32 pixels size.

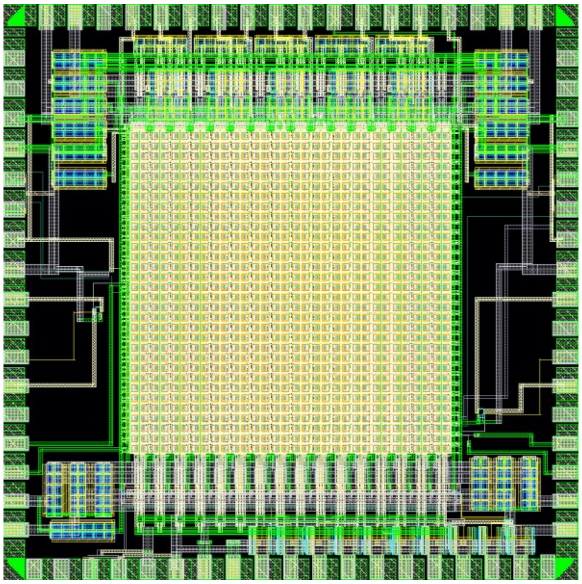


Fig. 5 ASIC prototype design.

4. CONCLUSIONS

In order to test the performance of the full system, a demo of the EUV channel which includes all novel sub-subsystems will be realized and tested (Fig.6). Novel sub-system, as detector and optical components, will be previously characterized to assess their individual final performance. The coating stability in space environment is independently tested though other research activities [24 - 27]. A detailed alignment plan has been conceived in order to acquire the doublet line at 91 nm emitted by an Ar gas in a hollow cathode source with the detector demo. We expect to prove the resolution and the high efficiency of the system.

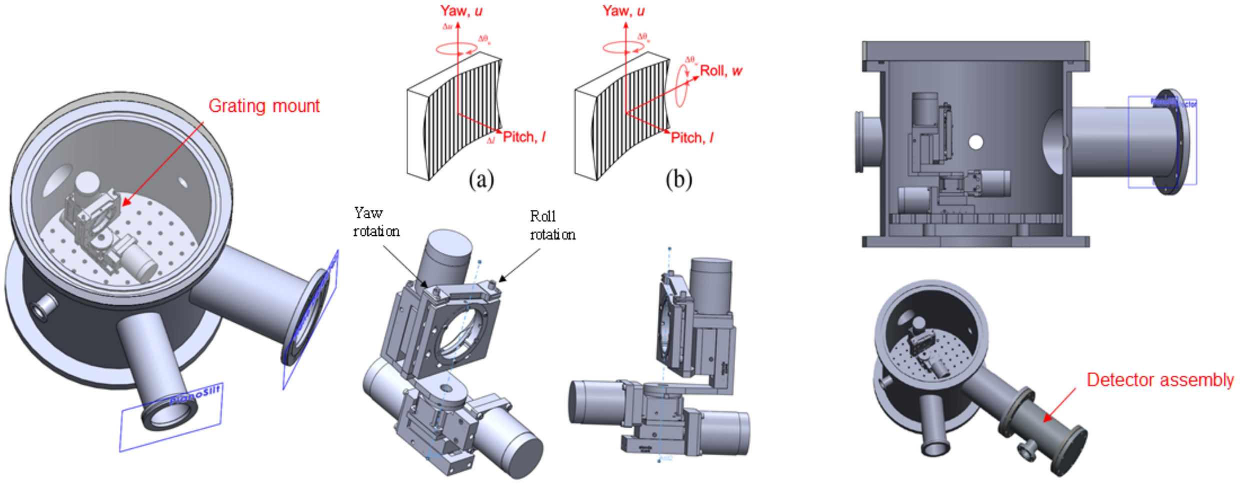


Fig.6 Opto-mechanical parts for the demo realization.

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