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Development of the Wide Field Imager for Athena

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ABSTRACT

The WFI (Wide Field Imager) instrument is planned to be one of two complementary focal plane cameras on ESA's next X-ray observatory Athena. It combines unprecedented survey power through its large field of view of 40 arcmin x 40 arcmin together with excellent count-rate capability (≥ 1 Crab). The energy resolution of the silicon sensor is state-of-the-art in the energy band of interest from 0.2 keV to 15 keV, e.g. the full width at half maximum of a line at 6 keV will be ≤ 150 eV until the end of the nominal mission phase. This performance is accomplished by using DEPFET active pixel sensors with a pixel size of 130 µm x 130 µm well suited to the on-axis angular resolution of 5 arcsec of the mirror system. Each DEPFET pixel is a combined detector-amplifier structure with a MOSFET integrated onto a fully depleted 450 µm thick silicon bulk. Two different types of DEPFET sensors are planned for the WFI instrument: A set of four large-area sensors to cover the physical size of 14 cm x 14 cm in the focal plane and a single smaller gateable DEPFET sensor matrix optimized for high count-rate observations. Here we present the conceptual design of the instrument with focus on the critical subsystems and describe the instrument performance expectations. An outline of the model philosophy and the project organization completes the presentation.

Keywords: Active pixel sensor, Athena, DEPFET, focal plane camera, Hot and Energetic Universe, WFI, X-ray astronomy, X-ray detector.

1. INTRODUCTION

The Advanced Telescope for High ENergy Astrophysics (Athena) will be the next large-class X-ray observatory of the European Space Agency (ESA) with a launch anticipated for 2028[1]. It is designed to answer two important astrophysical questions about the assembly of ordinary matter into large scale structures and the growth of supermassive black holes. The science theme of Athena, "The Hot and Energetic Universe" was endorsed by ESA in November 2013, and the Athena mission proposal has been accepted in June 2014.

In the Athena concept, a single large-aperture X-ray telescope based on silicon pore optics technology[2] images X-ray photons onto one of two complementary and interchangeable focal plane instruments: The X-ray Integral Field Unit (X-IFU) and the Wide Field Imager (WFI). The X-IFU provides very high spectral resolution over a small field of view by using transition edge sensors operated at cryogenic temperatures[3]. The WFI will have two independent focal positions, one with four detectors covering the very large field of view of 40 arcmin x 40 arcmin and a second, smaller detector featuring high throughput and low pile-up for observations of bright point sources. In both cases, silicon active pixel sensors of DEPFET type will be used, however each will be tailored specifically to the two different tasks. They have in

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common the good spectral resolution over a broad energy band (0.2 keV – 15 keV), e.g. a FWHM(5.9keV) ≤ 150eV throughout the mission.

The conceptual design and function of the WFI instrument is presented in the next section. The focal plane and camera characteristics are described in section 3. A description of the thermal design and the detector electronics is given in section 4. The model philosophy and project organization conclude the description of the WFI camera for the Athena project.

2. WFI CONCEPTUAL DESIGN

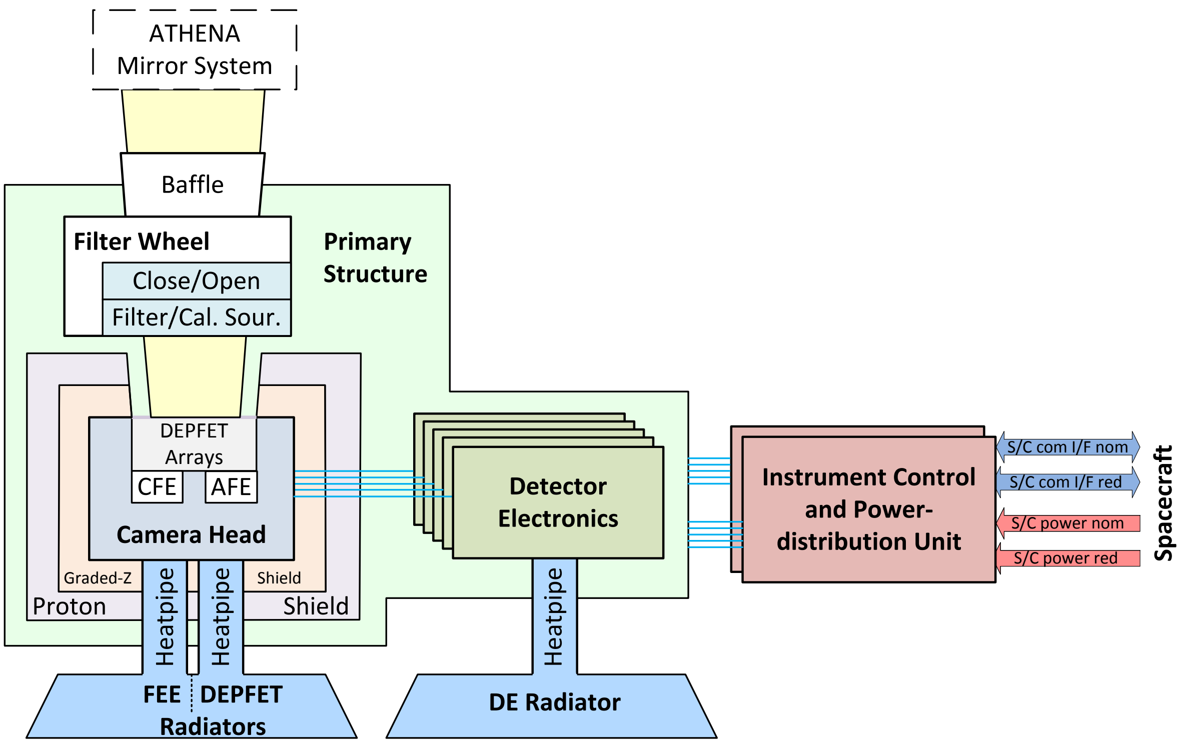

Figure 1: Block diagram of the WFI instrument with its various subsystems and interfaces. The camera head comprises as main components the DEPFET sensor arrays, the analogue front-end electronics (AFE) ASICs for readout of the DEPFET signals, and the Switcher ASICs as control front-end electronics (CFE).

Figure 1 gives an overview about the various subsystems of the WFI. A filter wheel controls the photon flux on the focal plane detectors. Four filter slots are envisioned: i) a visible light and UV light blocking filter, ii) an open position for evacuation, which permits also observations with high quantum efficiency at low X-ray energies, iii) a closed position for background measurements and sensor protection, and iv) an on-board calibration source that facilitates recalibration of the camera during the mission. A stray light baffle is mounted directly in front of the filter wheel as part of the baffling system between the mirrors and the camera (see Figure 2).
The energy, incidence position, and arrival time of the X-ray photons are measured by active pixel sensors (APS) of DEPFET type. The WFI provides two different detector options for that purpose: The large field of view of 40 arcmin x 40 arcmin is enabled by four identical large-area detector quadrants and the high count-rate capability is permitted by a special type of DEPFET APS with small area and split full frame readout. The control and readout of each sensor is accomplished by the use of front-end ASICs, called Switcher and VERITAS-2 that are developed for operation of the DEPFET sensors. The detectors are surrounded by a graded Z-shield to minimize instrumental background and a proton shield to reduce radiation damage. It is necessary to cool the silicon sensors to a temperature region of -70°C and -80°C in order to reduce the thermal generation current arising from radiation damage and maybe micrometeoroid impacts. The front-end electronics is operated at a more moderate temperature range (T=-20°C to 0°C).

However, the thermal gradient between sensor and front-end board has to be limited because there is a small but not negligible thermal coupling. Passive cooling is sufficient for both units and heat pipes will establish the thermal link to the dedicated radiator panels.

All four large quadrants and each of the two halves of the high count-rate optimized sensor are connected with flexible leads to dedicated detector electronics boxes. The detector electronics digitizes the analogue signals and performs the event detection and pre-processing. Furthermore, it provides the dynamic control as well as biasing of the sensor and front-end electronics. Each detector electronics is located next to the corresponding detector. As most of the WFI power is consumed by the detector electronics, it is also cooled by dedicated radiators and the thermal link is again accomplished by heat pipes.

The communication interface between the spacecraft and the WFI instrument is established by the Interface Control and Power Distribution Unit (ICPU) via, e.g. SpaceWire. The ICPU controls the operation of the six detector units and merges their six data streams. It is furthermore responsible for filter wheel control and thermal control of the focal plane. Finally, the ICPU also interfaces the WFI to the spacecraft power bus and distributes the power to the other WFI subsystems. A redundant ICPU is envisaged in the WFI concept in order to obtain a 'single point failure'-free design.

In contrast to the other subsystems that are mounted close together on the WFI primary structure, the ICPU can be accommodated in some distance underneath the instrument platform. A schematic view of the WFI instrument is shown in Figure 2. The camera head containing the detectors is located in the center of the instrument. In the course of the instrument development[4],[5],[6], an appropriate focal plane layout has been designed. It is described in the next section.

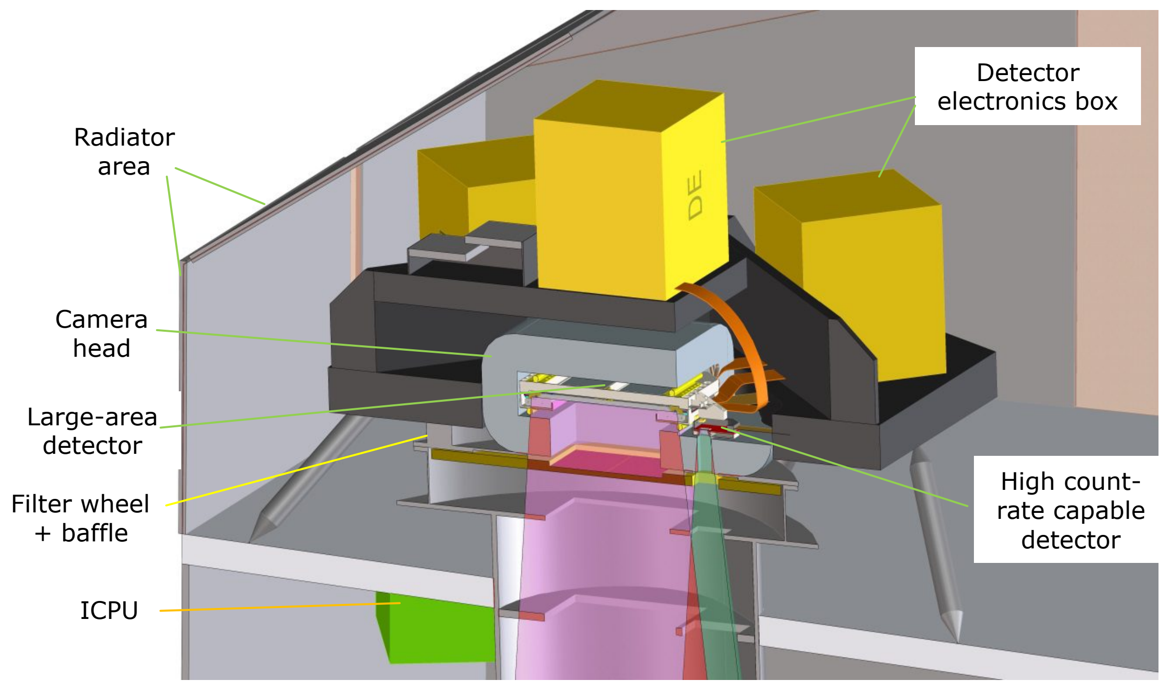

Figure 2: Schematic view of the WFI instrument with the camera head in the center comprising the large detector (on the left-hand side) and the small high count-rate capable detector (on the right-hand side). The latter is mounted out of focus in order to distribute the photons of bright point sources over the entire detector area. The front-end electronics boards of the camera head are connected with short flexible leads to the detector electronics boxes located in the vicinity. The filter wheel with optical stray light baffle is mounted in front of the camera head and extends to the instrument platform. The primary structure of the WFI carries the subsystems and is mounted on top of the instrument platform. Only the ICPU boxes (nominal and redundant) are located underneath. The ICPU is the electrical and telemetry interface to the spacecraft. The radiator areas cover the instrument.

3. FOCAL PLANE LAYOUT AND CAMERA CHARACTERISTICS

3.1. Focal plane layout

The WFI camera provides a large field of view and a high count-rate capability. For these purposes, it features two detectors, a large-area detector and a fast small detector (see also Figure 3). Both are read out in a rolling shutter mode, i.e. pixel row by pixel row. Here, all pixels of one row are read out simultaneously by a corresponding number of VERITAS-2 ASIC channels[7].

The large-area detector comprises a 2 x 2 mosaic of independent and identical detectors. In contrast to previous DEPFET detectors having interfaces at three or four sides, these WFI detectors are designed to be completely controlled and read out a two sides only (two-side buttability). This means that one side is connected to the Switcher ASICs and the other side to the VERITAS ASICs. This concept avoids the arrangement of any electronics behind the sensor and thereby the fluorescence photon contribution to the instrument background is minimized.

The high count-rate capable detector comprises just one DEPFET device, split in two halves for readout. The resulting two detector units are largely but not completely independent from each other. A standard DEPFET is not the best choice for a fast detector as photons hitting a standard DEPFET during the time of signal processing will receive a wrong energy assignment. This disadvantage can be avoided using a gateable DEPFET with additional signal storage region per pixel[8]. First prototypes of such devices have successfully been produced and are currently under test. Further development for the high count-rate WFI detector will be necessary, but the benefit is a clearly better spectral response compared to a standard DEPFET detector because energy misfits are prevented as confirmed by measurements[8].

The front-end electronics is placed adjacent to the sensors. The VERITAS and Switcher ASICs (each with 64 channels) are wire-bonded to the sensor chips. The DEPFET sensor support structure is, apart from the bond wires, thermally decoupled from the front-end electronics with the ASICs. This focal plane detector concept provides optimum detectors for either observation of large objects or very bright point sources. Depending on the object of interest, the mirror system will be tilted. Thereby, the source photons are focused to one out of three focal plane detectors: X-IFU, WFI large field of view detector or WFI high-count rate capable detector in order to permit on-axis observations.

For determination of the appropriate pixel size, a tradeoff has been carried out between a negligible degradation of the point spread function (PSF) of 5 arcsec HEW (or 3 arcsec as goal) of the mirror system and an increase in readout time by a larger number of pixels in the focal plane. The result is an optimum pixel size of 130 µm x 130 µm (corresponding to an angular element of 2.2 arcsec x 2.2 arcsec) for both types of detectors. This pixel size allows a sufficiently accurate source position reconstruction. We note that the actual spatial resolution of the detector is better than the one given by the pixel size. This is due to the occurrence of split events and their signal charge distribution (over up to four pixels) as a function of the photon incidence position and energy.

3.2. Large-area detector

The large-area detector comprises a total number of 1024 x 1024 pixels subdivided into four quadrants. The sensor and the front-end electronics are mounted on separate support structures for thermal decoupling. The electrical interfaces are wire bonds. The cross-shaped support structure for the four DEPFET chips causes insensitive regions but can be accounted for by observing with an appropriate dithering pattern. We aim for a readout speed of 2.5 µs per row with the VERITAS-2 ASIC that is presently under development. This will allow to read out the entire frame in 1.3 ms. The improvement in readout speed by about a factor of two is not the only difference to the DEPFET detector used for the MIXS instrument on-board of ESA's BepiColombo satellite to Mercury[9]. The WFI observations shall benefit from an optimized DEPFET transistor geometry and an enhanced fabrication technology. Such prototype devices for the large-area WFI detector have already been designed and are currently produced in the semiconductor laboratory of Max-Planck-Society.

3.3. High count-rate capable detector

The DEPFET matrix of the high count-rate capable WFI detector consists of 64 rows and 64 channels. For an increase of the frame rate by a factor of two, the matrix is split into two halves that are read out simultaneously, i.e. it is operated in the so-called 'split full frame mode'. The time resolution is thereby 80 µs per frame. Simulations showed that the high count-rate capability can be further improved by operating the detector out of focus. By appropriate defocusing, the photons of a bright point source are distributed over the entire detector area. Thereby the photon flux per pixel decreases accordingly (see section 3.4). This yields a higher throughput and lower pile-up compared to the alternative approach of operating the DEPFET in window mode.

Two concepts are presently studied for the gateable DEPFET with additional signal storage region per pixel. One concept uses two DEPFET transistors per pixel with alternating functions of signal storage and signal processing. In the alternative concept, the signal charge is transferred from the storage region inside the pixel to the internal gate of the DEPFET transistor. Afterwards, the event signals can be read out undisturbed by collecting the new signal charges of the next frame.

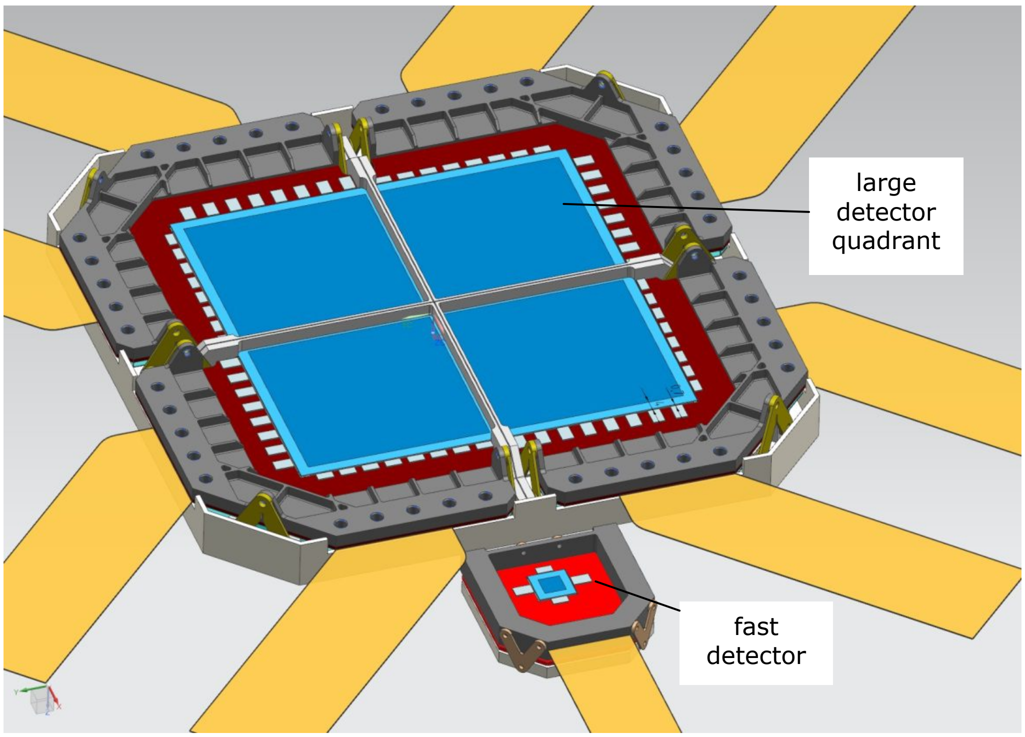

Figure 3: Focal plane design of the WFI instrument: The large-area detector consists of four quadrants to span the large field of view of 40 arcmin x 40 arcmin. Each quadrant comprises a DEPFET sensor chip with 512 rows and 512 channels and the associated front-end electronics. Main components of the front-end electronics are the eight VERITAS-2 ASICs for readout of the DEPFET signals, the eight Switcher ASICs for control of the DEPFET sensor, and the flexible leads as electrical interfaces to the detector electronics. The high count-rate capable detector is shown at the bottom in the figure with two VERITAS-2 and two Switcher ASICs.

Details of the WFI DEPFET detector concept, the DEPFET sensor, and the readout ASIC are described in ref. [5],[6],[7],[8].

3.4. High count-rate capability

With rising count-rate, the probability increases that two photons hit the detector in the same or in neighboring pixels during the integration time of a frame. As a result, the throughput drops and pile-up is no more negligible. Throughput is defined as the ratio of the number of events with valid pattern (single, double, triple, quadruple) and the total number of incident photons. Pile-up probability means the fraction of events affected by energy or pattern pile-up among all valid event patterns. Both effects have been studied as a function of photon flux by SIXTE simulations[10]. Optimum results are achieved for both parameters by use of the small detector and defocusing the point spread function (PSF), i.e. mount it about 35 mm out-of-focus. This gives better results than operating either the small or the large detector in window mode and focused. We achieve approx. 95% throughput and <1% pile-up for a 1 Crab photon flux (see Figure 4).

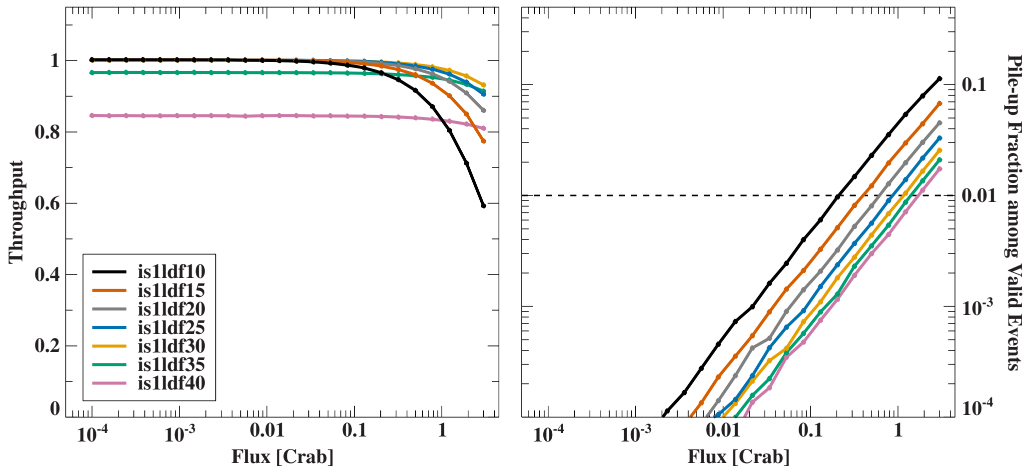

Figure 4: SIXTE performance simulations of the high count-rate capable WFI detector for different out-of-focus positions (10 mm up to 40 mm), taking into account all valid split patterns. The bottom axis represents the source brightness as a fraction of 1 Crab. Left: Throughput representing the number of valid split patterns divided by the number of simulated photons. Right: Fraction of pile-up events among the valid split patterns. The horizontal dashed line denotes a pile-up of 1% as specified in the Athena science requirements. Defocusing by about 35 mm, yields the best results for both parameters (see curve 'is1ldf35' and Figure 5) as the point spread function matches approximately the detector area.

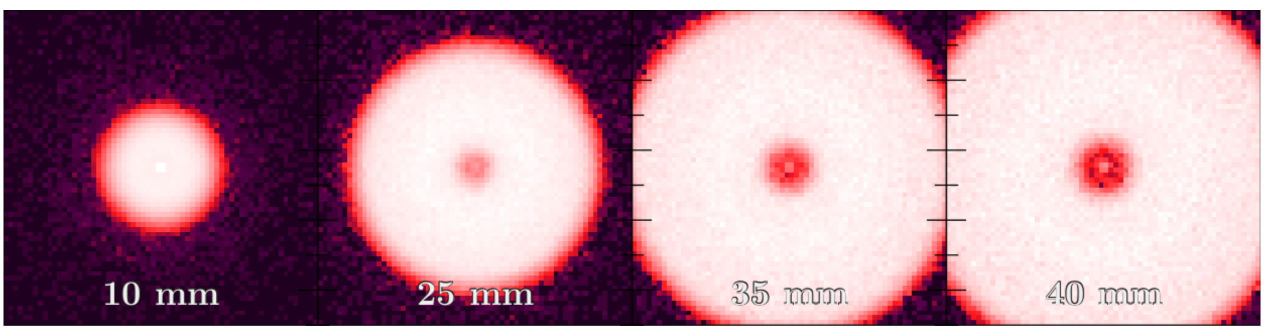

Figure 5: The point source image as seen by the high count-rate capable detector (64 x 64 pixels) for different out-of-focus positions: 10 mm, 25 mm, 35 mm, and 40 mm (relating to a focal length of 12 m). The photons of the widened PSF are distributed over almost the entire image for an offset of 35 mm. For even higher offset values, e.g. 40 mm, the width of the photon distribution is larger than the detector. This explains the drop in throughput, as seen in Figure 4 (see curve 'is1ldf40'). The surface brightness is scaled logarithmically from white (bright) to dark (faint).

3.5. WFI camera characteristics

Table 1 gives an overview of the main requirements and performance parameters of the WFI instrument. The characteristics are based on the current conceptual design based on analysis and simulations. The quantum efficiency at low X-ray energies depends strongly on the light blocking layers. For the on-chip filter, a 90 nm thin aluminum layer can be deposited on the DEPFET photon entrance window on top of a 20 nm thick Si_3N_4 and 30 nm thick SiO_2 layer stack. An expedient choice for the external filter (mounted in the filter wheel) is a 40 nm thin aluminum layer deposited on a 200 nm thick polyimide foil and to support this by a stainless steel mesh with 95% opening. Figure 6 shows the resulting quantum efficiency as function of energy for this possible combination of on-chip and external optical blocking filter.

Table 1: WFI detector characteristics

Parameter	**Characteristics**
Energy range	0.2 keV – 15 keV
Pixel size	130 µm x 130 µm pixel size (corr. to 2.2 arcsec x 2.2 arcsec)
Operating mode	rolling shutter (min. power consumption) full frame mode optional: window mode
High count-rate capable detector	64 x 64 pixel split full frame readout gateable DEPFET type with additional signal storage region time resolution: 80 µs 1 Crab: 90% throughput and 1% pile-up (mounted defocused) field of view: 143 arcsec x 143 arcsec
Large-area DEPFET detector	4 quadrants each with 512 x 512 pixel non-gateable DEPFET type time resolution: 1.3 ms field of view: 40 arcmin x 40 arcmin
Quantum efficiency incl. external filter (possible configuration: on-chip: 90 nm Al + 30 nm SiO_2 + 20 nm Si_3N_4; external filter: 40 nm Al + 200 nm PI + mesh 95%)	>20% @ 277 eV >80% @ 1 keV >90% @ 10 keV transmission of visible light: 3 x 10^{-7} transmission of UV light (643 A - 1932 A): <10^{-9}
Energy resolution	FWHM (6 keV) ≤ 150 eV
Non X-ray background (L2 orbit)	< 5 × 10^{-3} cts cm^{-2} s^{-1} keV^{-1}

The quantum efficiency increases with photon energy (apart from the characteristic absorption edges) up to 8 keV but subsequently drops due to the decreasing probability for X-ray absorption in the 450 µm thick and sensitive DEPFET chip. The high quantum efficiency is achieved by back-illumination of the unstructured photon entrance window in combination with full depletion of the 450 µm thick sensor chip.

As the DEPFET sensor is also sensitive to visible and UV light apart from X-rays, these photon intensities have to be attenuated by the blocking filters. The on-chip filter as described above decreases the transmission of visible light to a value of 3 x 10^{-5}. The suggested external filter diminishes the transmission of visible light by an additional factor 10^{-2}.

The luminosity of UV light peaks for massive stars between 643 A and 1932 A. The on-chip filter has a transmission of 4 x 10^{-4} at 653 A and 2 x 10^{-5} at 1932 A. The corresponding values for the external filter are 6 x 10^{-7} and 9 x 10^{-6}. The combination of on-chip and external filter gives accordingly a transmission of 3 x 10^{-10} at 653 A and 2 x 10^{-10} at a wavelength of 1932 A. Further details on the optical/UV blocking filters are given by Barbera et al. in ref.[11]. The on-chip and external filters for the large field of view and the fast sensor will be based on the same type of materials, however, the thicknesses will be properly tuned to take into account the different read-out times.

The mesh is presumably necessary for support of the thin and fragile filter foil against the acoustic noise arising during the launch of the satellite. In the first step of the development, the acoustic noise loads for the filter shall be reduced by optimum filter wheel design. In the next step, experimental tests have to verify the robustness of the filter assembly against acoustic noise[11].

An alternative solution would be to accommodate the filter and detector in a vacuum vessel, like done for the EPIC PN-camera on XMM-Newton, and launch it evacuated. However, this requires a higher mass for the camera and induces a single point failure risk due to the necessary door mechanism.

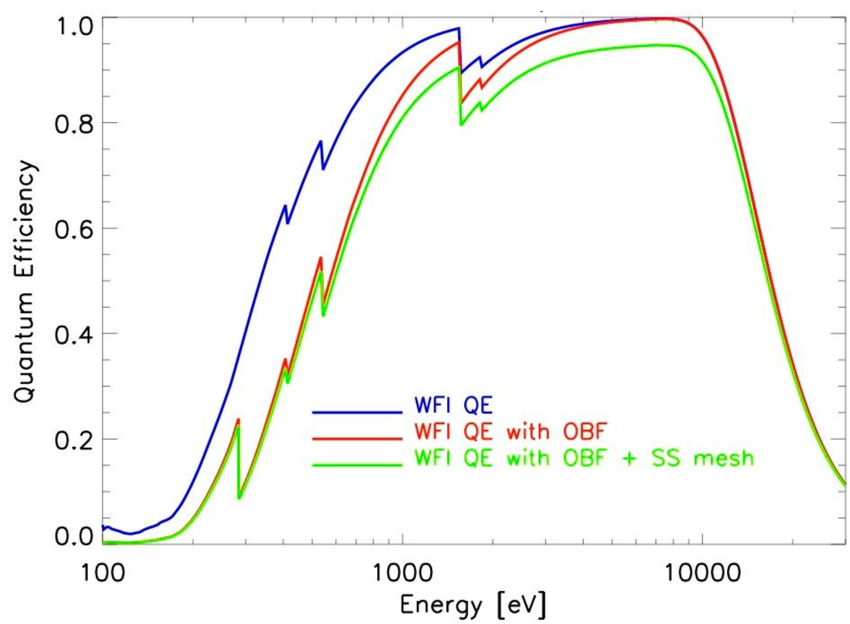

Figure 6: Quantum efficiency of a possible configuration for the WFI camera. With 90 nm Al deposited on the DEPFET chip including associated oxide and nitride layers, we achieve a quantum efficiency as shown by the upper (blue) curve. When the external optical blocking filter (OBF) with 40 nm Al deposited on a 200 nm thick polyimide substrate is moved in front of the detector, a total quantum efficiency results as displayed by the middle (red) curve. The issue of acoustic noise requires likely a supporting mesh, e.g. made of stainless steel. For this configuration, we get the quantum efficiency as shown in the lower (green) curve. Please note, observations are possible without external filter, i.e. with quantum efficiency according to the upper curve. Disadvantages are however firstly a higher contamination risk because of more adsorption of molecules from outside the camera at the cold sensor than at the warm filter. Secondly, the intensities of visible and UV light as well as of very soft protons are less attenuated by use of the on-chip blocking filter only.

4. DEVELOPMENT OF FURTHER WFI SUBSYSTEMS

For the so-called technology development activity phase of the Athena project, there have been three subsystems identified that have to be further developed to achieve the in ESA's call for L2 mission concepts required technological readiness level. These are the DEPFET detectors as the WFI key element, the optical blocking filter because of the potential susceptibility to acoustic noise, and the detector electronics as it has to provide high-speed data processing onboard of the satellite in real-time. Furthermore, the thermal design needs particular analysis in this early phase of the project as the large-area sensor shows optimum performance at low temperature and the power consumption of the high-speed electronics is high. Appropriate cooling of the subsystems is essential for optimum performance and long-term stability.

4.1. Thermal Design

The WFI instrument utilizes solely passive cooling with constant conductance heat pipes and radiators. Thus, the cooling concept employs no consumables or components with limited lifetime and no movable parts. The camera head and electronics need three separate cooling chains as there are three different temperature levels. A temperature down to approx. 190 K is envisaged for the focal plane sensors. The adjacent front-end electronics can be operated at a higher temperature but is inevitably thermally coupled to the sensors by the large number of wire bonds. By separating the sensors and the front-end electronics, a significant amount of radiator area can be saved, since most of the power is dissipated within the electronics. Nevertheless, the lower temperature level is challenging due to large amount of expected parasitics onto the sensors, caused by the warm environment. An electronics temperature of approx. 250 K compromises the two requirements. The detector electronics and ICPU shall be operated at a temperature of 280 K that does not affect the lifetime of the components. According to the temperature level, ethane heat pipes are needed for the sensor cooling, whereas standard ammonia heat pipes can be used for the front-end electronics and detector electronics.

Taking into account the active power dissipation of the individual subsystems and the parasitics (thermal radiation and thermal conduction), the calculation estimates a radiator with an overall area of 3 m^2. A large fraction of the area, 1.7 m^2, is needed for cooling of the detector electronics. Altogether, these six subsystems need a cooling power of 450 W.

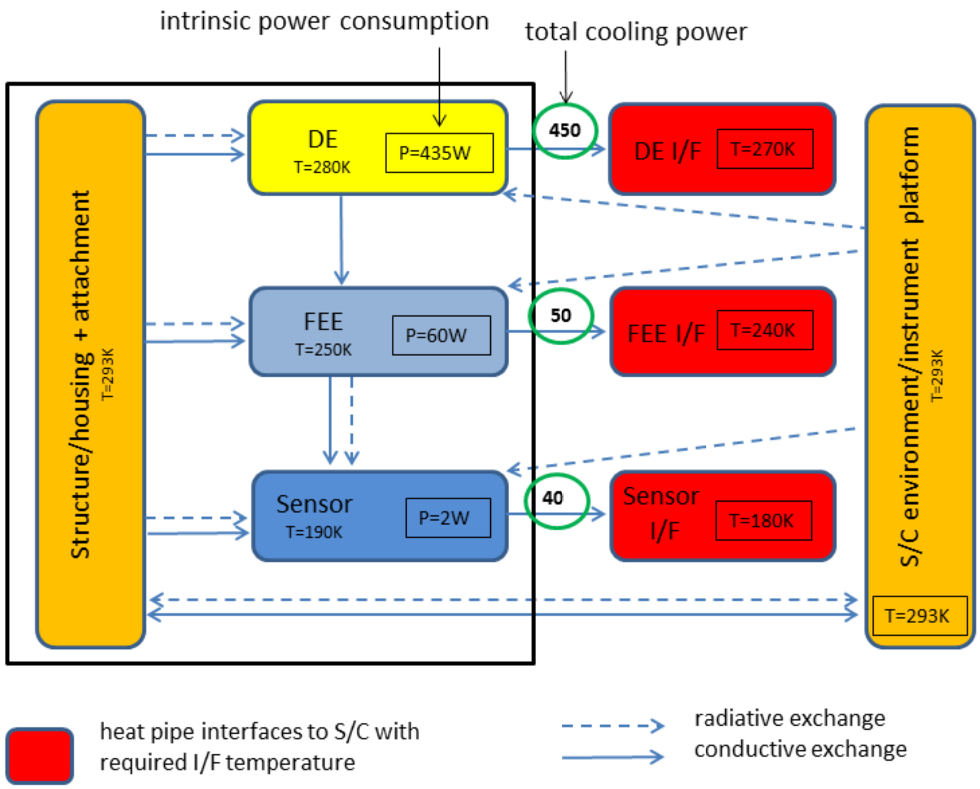

Figure 7: Preliminary thermal budget of the WFI. Given is the intrinsic power consumption as well as the required cooling power for the DEPFET sensors, the front-end electronics, and the detector electronics.

4.2. Detector Electronics

The extremely high data rate poses a challenge for the WFI electronics. An appropriate concept whose general architecture is shown in Figure 8 is being developed. The functionality is distributed among three modules:

i) Power conditioning: Analog and digital supply and bias voltages have to be generated for the sensor, the readout ASICs of VERITAS-2 type, and the Switcher control ASICs.

ii) Data processing: This functional unit contains the sequencer, the ADC array and the frame processor. The sequencer generates the sequence of signals in order to control, program, and synchronize the ASICs and the frame processor. The analog detector signals from the VERITAS-2 readout ASICs are converted into digital signals by an array of eight 14-bit ADCs per large detector quadrant respectively by one ADC for a high count-rate capable detector half. An FPGA-based processor performs all necessary corrections for the events in the so-called frame processor pipeline (see Figure 8). Event filtering is necessary on-board, otherwise the scheduled telemetry rate of the satellite at Lagrangian point L2 to the ground station would be exceeded by several orders of magnitude.

iii) ICPU interface: The detector electronics will be powered and controlled by the ICPU (e.g. selection of operating mode) and in return transfers science and housekeeping data to it.

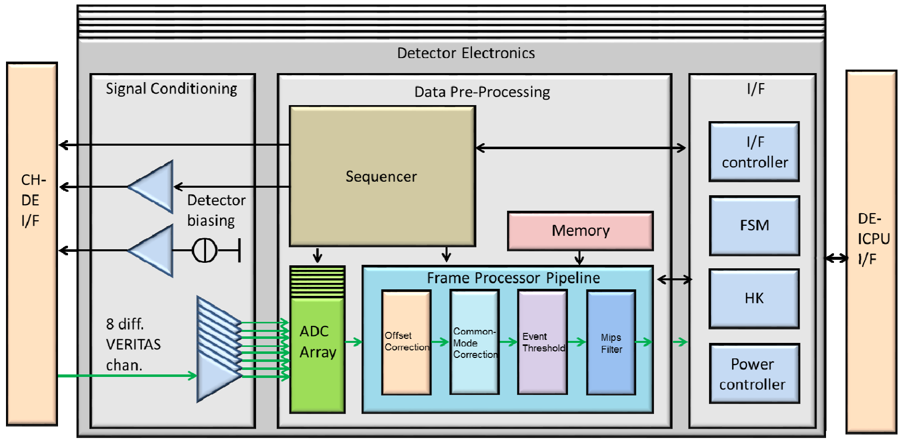

Figure 8: Block diagram of the detector electronics. It contains three blocks: signal conditioning for the detector, data pre-processing, and the interface to the ICPU.

The pixel rate that needs to be pre-processed on-board in real-time is the following for the large detector: Each of the four quadrants provides the signals of 512 channels within 2.5 µs. This results in a rate of 205 Mpixel/s per quadrant. For observations with the high-count rate capable detector, the signals of 26 Mpixel/s have to be pre-processed for each half.

5. MODEL PHILOSOPHY AND PROJECT ORGANIZATION

5.1. WFI model philosophy and main budgets

A classical model philosophy has been selected for the development of the WFI instrument on Athena. In the first project phase, a breadboard model (BB) is beeing developed to demonstrate the availability of the appropriate technology. In the next step, an engineering model (EM), a structural and thermal model (STM) as well as a model showing the electrical functions (EFM) will be assembled and tested. After the critical design review, the development of the WFI qualification model (QM) shall take place including the execution of all necessary qualification tests. Finally, the WFI flight camera (FM) will be assembled, tested, calibrated, and delivered to ESA for integration into the satellite. Furthermore, we intend to develop spare models of the most critical subsystems.

According to the conceptual design of the WFI camera, the power needed for the instrument has been estimated to 684 W and its mass amounts presumably to 256 kg (respectively 288 kg if a vacuum vessel will be needed for the protection of the optical blocking filter). The size of the WFI instrument will be approximately 0.8 m x 1.2 m x 0.6 m large (without radiator that is planned to be mounted on the instrument platform). The science data rate depends on the observed source but typical values will range from 10 kbit/s to 2 Mbit/s after data compression. The additional housekeeping data rate for the instrument amounts to approximately 3 kbit/s.

5.2. Project schedule and organization

A proto-consortium has been founded for the WFI instrument development that comprises presently scientific institutes in Austria, Denmark, France, Great Britain, Italy, Poland, and Germany. Further potential partners from USA, Japan, and Portugal are likely to join at a later stage. The WFI instrument development is led by MPE (Max-Planck-Institute for extraterrestrial physics). The key personnel of the WFI team is Kirpal Nandra as the principal investigator, Norbert Meidinger (project manager), Markus Plattner (lead system engineer), and Arne Rau (project scientist).

ESA started phase A of the project in July 2015. The next project milestone is the announcement of opportunity for the instruments that will presumably come about in summer 2016. An important step will then be the mission adoption by ESA, which is envisaged for 2020.

6. SUMMARY

The conceptual design for the wide field imager instrument for Athena has been introduced. The key element, the focal plane layout, needed attention in particular because various requirements to the WFI have to be taken into account. As a result we have a large detector array for the wide field observations and a separated high count-rate capable detector of different type for the observation of bright point sources. Both detectors have to be supplied by a large number of voltages and control signals. The detector output signals need fast processing in real-time. These are the main tasks of the detector electronics with an FPGA-based frame processor apart from interfacing the instrument control and power distribution unit ICPU. Detectors as well as the detector electronics have to be thermally controlled and for this purpose cooling by radiators is necessary. A thermal concept for the WFI has been drafted based on the expected active power consumptions and parasitic heat flows. Special attention is also paid to the ultra-thin optical blocking filters, which are split into two parts: an aluminium layer can be directly deposited on the DEPFET sensor chip and an external filter (mounted in the filter wheel) is furthermore available to attenuate visible and UV light during observations. However, analysis and tests are needed to make sure that the external filter will not be damaged by the acoustic noise arising during satellite launch.

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