Gamma-ray Bursts: 15 Years of GRB Afterglows
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DESIGN, CONSTRUCTION AND PERFORMANCE OF THE DETECTOR FOR UFFO BURST ALERT & TRIGGER TELESCOPE

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Abstract. One of the key aspects of the upcoming Ultra-Fast Flash Observatory (UFFO) pathfinder for Gamma Ray Bursts (GRBs) identification is the UFFO Burst Alert & Trigger Telescope (UBAT). The scientific propose of UBAT is to detect and locate as fast as possible the GRBs in the sky. This is achieved by using a coded mask aperture camera scheme with a wide field of view (FOV) and selecting a X-ray detector of high quantum efficiency and large detection area. This X-ray detector of high quantum efficiency and large detection area is called the UBAT detector. The UBAT detector consists of 48×48 Yttrium Oxyorthosilicate (YSO) scintillator crystal arrays and Multi Anode Photomultiplier Tubes (MAPMTs), analog electronics equipped with ASIC chips, digital electronics equipped with Field Programmable Gate Array (FPGA) chips, and a mechanical structure that supports all components of the UBAT detector. The total number of the pixels in the UBAT detector is 2304, and the total effective detection area is 191 cm^2. We will present the design and construction, and performance of the UBAT detector including the responses of the UBAT detector to X-ray sources.

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Table 1. Specifications of the UBAT.

Mass	10 kg
Power consumption	10 W
Volume	400(L) × 400(W) × 382.5 (H) mm^3
Pixel size	2.88 × 2.88 mm^2
Number of pixels	48 × 48
Field of View	1.83 sr (90.2° × 90.2°)
Energy range	15 – 150 keV
GRB location accuracy	≤10 arcmin for $>7\sigma$

1 Introduction

The prime scientific purpose of the Ultra-Fast Flash Observatory (UFFO) pathfinder is to observe the early UV/optical photons from GRBs (Park *et al.* 2013). The UFFO pathfinder was installed in the Russian Satellite *Lomonosov* which will be launched in 2013. The UFFO pathfinder has two key components. The one key component is the wide field of view X-ray telescope called the UFFO Burst Alert & Trigger Telescope (UBAT). The other key component is the UV/optical telescope equipped with a slewing mirror and also Ritchey-Chretien telescope. The UBAT is able to detect X-rays from GRBs, and then to determine the location of GRBs. The location of GRBs is passed to the SMT which rotates (*i.e. point*) its slewing mirror to the GRBs. The UV/optical lights will be directed to the on-axis of the Ritchey-Chretien telescope by the slewing mirror pointed to the GRBs which the source emitting the UV/optical lights. The UBAT telescope is described in this paper, and the description and detail of the SMT will be found elsewhere (Jeong *et al.* 2013).

2 Specification of the UFFO burst alert & trigger telescope

The UBAT will trigger GRBs and determine their locations by detecting X-rays from them. Its mass and power consumption is 10 kg and 10 W, respectively, due to the constraint given by the overall *Lomonosov* satellite mission. The specification of the UBAT is shown in Table 1.

3 Components and assembly of the UFFO burst alert & trigger telescope

The UBAT consists of the code mask, hopper and detector as shown in Figure 1. The coded mask is a tungsten plate with a random pattern of opens and blocks that transmit or stops X-rays from GRBs. The hopper, made of tungsten, supports the coded mask as well as the UBAT detector.

The UBAT detector consists of Yttrium Oxyorthosilicate (YSO) scintillator crystal arrays, Multi Anode Photomultiplier Tubes (MAPMTs), analog and digital

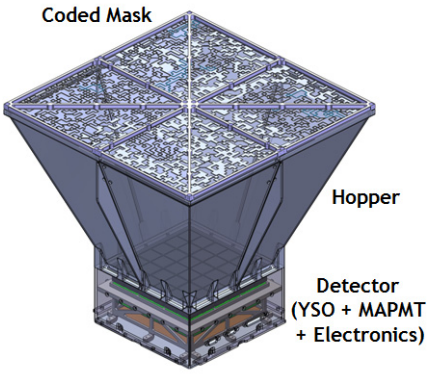

Fig. 1. The UFFO Burst Alert & Trigger Telescope.

electronics, and power board. Figure 2 shows the components of the UBAT detector. Either a YSO crystal array or a MAPMT has 64 pixels in the 8×8 array with the same pixel size of 2.88×2.88 mm^2. The thickness of the YSO crystal is 3 mm. Each YSO crystal array is mounted on top of a MAPMT using optical glue. There are 36 pairs of the YSO crystal array and MAPMT in the 6×6 array in the UBAT detector. The YSO crystal array converts incident X-rays to the optical scintillating lights. The scintillating lights are then transmitted by refraction to the corresponding MAPMT where the lights are converted to photo-electrons in the photo-cathode. These photo-electrons are then multiplied by the factor of $\sim 10^6$ as the electrons travel along several dynodes inside the MAPMT. The multiplied electrons, *i.e.* charges, are fed to the analog Application Specific Integrated Circuit (ASIC) chips mounted on the analog board. The analog ASIC chips output the digitized photon counting and energy of X-rays. These digitized values of counting and energy of X-rays are transferred to the digital board, equipped with Field Programmable Gate Array (FPGA) chips, where the digital values are summed or subject to other digital operations. The power board produces the low voltage power for analog and digital electronics as well as the high voltage for MAPMTs. The UBAT detector, inside the full UBAT, after assembled with its components is shown in Figure 3.

4 Performance of the UFFO burst alert & trigger telescope

Am-241 radioactive sources emit X-rays of 60 keV energy. They also emits X-rays of low energy, and the average energy of these low energy X-rays is about 20 keV. Several Am-241 sources are placed upon the YSO crystal arrays to test the response of the UBAT detector. Figure 4 shows the clear response, *i.e.* photon counting, of the UBAT detector to eight collimated Am-241 sources. The accuracy in the X-ray source location of the UBAT is currently underway using an X-ray source at a far distance from the UBAT.

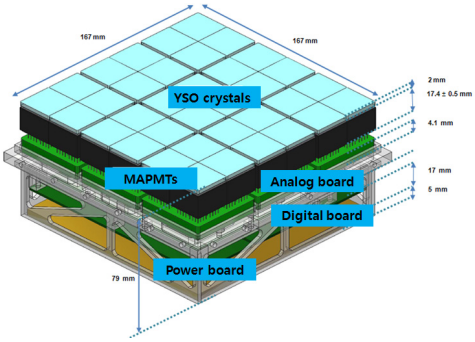

Fig. 2. The UBAT detector.

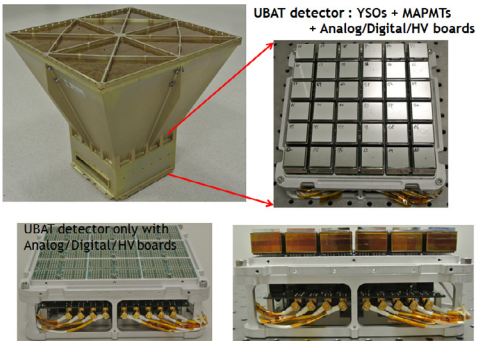

Fig. 3. The assembled UBAT and its detector.

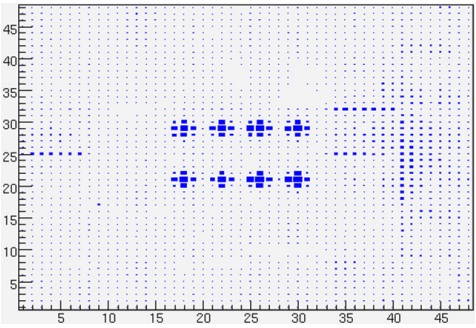

Fig. 4. The response of the UBAT detector to the collimated Am-241 X-ray source.

5 Conclusion

We have designed and constructed the UFFO Burst Alert & Trigger Telescope using a coded mask, Yttrium Oxyorthosilicate (YSO) scintillator crystal arrays,

Multi Anode Photomultiplier Tubes, and analog and digital electronics. The UBAT assembled with these components successfully demonstrated its X-ray detection capability for the energy range from 15 keV to 150 keV. It was integrated onto the Ultra-Fast Flash Observatory (UFFO) pathfinder, which was, in turn, installed onto the *Lomonosov* satellite. The UBAT is expected to detect X-rays from Gamma Ray Bursts and determine the location of tens of GRBs every year. The location of the GRBs will be passed to the SMT in the UFFO. The SMT will point its slewing mirror to the GRBs to detect the very early UV/optical photons from them, which is the unchartered area in the field of the GRB observation.

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