The Hard X-ray Imager for ASTRO-H mission

Shin Watanabe[1,2], Motohide Kokubun[1], Rie Sato[1],Tadayuki Takahashi[1,2], Kazuhiro Nakazawa[2], Yasushi Fukazawa[3], Tsunefumi Mizuno[3], Hiromitsu Takahashi[3], Jun Kataoka[4], Hiroyasu Tajima[5], Takaaki Tanaka[5], Yukikatsu Terada[6], Kazutaka Yamaoka[7] and ASTRO-H/HXI team

[1] ISAS/JAXA, [2] University of Tokyo, [3] Hiroshima University,
[4] Waseda University, [5] KIPAC/Stanford, [6] Saitama University,
[7] Aoyama Gakuin University
E-mail(SW): watanabe@astro.isas.jaxa.jp

Abstract

We have been developing the hard X-ray imager (HXI) as on board instruments of the ASTRO-H satellite. This paper describes the HXI basic concept and the expected performance.

Key words: ASTRO-H, Hard X-ray Imager, HXI

1. Introduction

Hard X-ray Imager (HXI) is one of focal plane detectors of ASTRO-H, which is the 6th Japanese X-ray astronomical satellite scheduled to be launched around 2014. Among the major objectives is achieving high sensitivity observation with focusing and imaging capabilities in the 5–80 keV energy region. The ASTRO-H satellite will carry two hard X-ray telescopes that feature multilayer supermirrors assembled in grazing incident X-ray telescopes. Two identical imagers are located at focal points of two HXTs. The focal length of the HXT is 12 m. To realize the focal length, ASTRO-H has a extendable optical bench (EOB), which is extended in orbit. Two HXIs are mounted on the EOB plate.

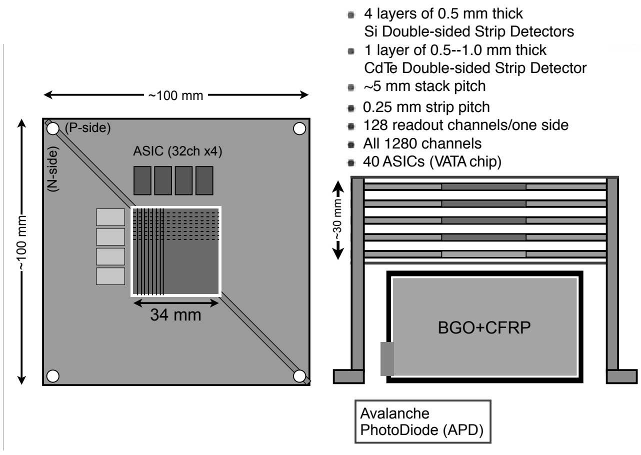

Fig. 1. The HXI Configuration.

2. HXI Basic Concept

From both of scientific and technical point of views, there are many requirements which should be met by the focal-plane imaging detector. HXIs require high detection efficiency in the hard X-ray region of 5–80 keV, sufficient position resolution for the point spread function of HXTs, and, the large geometrical size of the imagers to cover the field of view of HXTs. Moreover, low detector background succeeded to Suzaku HXD is essential for the high sensitivity observation.

Fig. 1 shows the current design of the HXI configuration. The HXI consists of four-layers of 0.5 mm thick double-sided strip detectors and one layer of 0.5–1 mm thick CdTe double-sided strip detector. In this configuration, lower energy X-ray photons will be absorbed in the Si part, while higher energy X-ray photons go through the Si part and are detected with the CdTe part. Fast timing response of the double-sided strip detectors allows us to place the whole detector inside the well of the active shield made of BGO. Signal from the BGO shield is used to reject background events in the same way as Suzaku HXD. With this configuration, the lower energy spectrum obtained with the Si part, is less contaminated with the background due to activation in heavy material, such as Cd and Te. The low detector background of Si detector inside the BGO active shield has been established in the data obtained with the Suzaku HXD Si-PIN. In Table 1, the HXI specification is summarized.

3. Expected Performance

3.1. Efficiency and Effective Area

By using a Monte Carlo simulation, the detection efficiency of the HXI was calculated. The upper panel

Table 1. HXI Specification

Configuration	4 layers of 0.5 mm thick Si, 1 layer of 0.5–1 mm thick CdTe, and BGO active shield
Mass	38 kg / 1 HXI
Power	30 W / 1 HXI
Energy Range	5–80 keV
Imaging Area	32×32 mm^2
Field of View	9×9 arcmin^2
Position Resolution	250 μm
Time Resolution	< 10 μsec
Energy Resolution	< 2 keV (FWHM at 60 keV)
Detection Efficiency	80% (at 60 keV)
Detector Background	< 1–3×10^{-4} ph/cm^2/s/keV
Operating Temperature	~ -20°C

of Fig. 2 shows the HXI detection efficiency. In this Monte Carlo simulation, the HXI consists of four layers of 0.5 mm thick Si detectors and one layer of 0.75 mm thick CdTe detector.

The HXT-HXI effective area combined the effective area of HXT and the detection efficiency of HXI is shown in the lower panel of Fig. 2. This plot shows the effective area for one HXT-HXI system.

3.2. Detector Background

An estimated background spectrum of HXI is shown in Fig. 3. This background includes a Si background due to albedo neutron and a CdTe background due to CdTe activation. The albedo neutron background, which is the dominant component of the Suzaku HXD Si-PIN background, is derived from the background data of Suzaku HXD Si-PIN. The neutron background level is scaled based on the Si volumes. The CdTe activation background is modeled based on the proton beam experiments.

The grey lines in Fig. 3 shows the the background level after an optimization. The HXI stack configuration and individual readout provide information on the interaction depth. This depth information is very useful to reduce the background, because we can expect that low energy X-rays interact in the upper layers and, therefore, we can reject low energy events detected in lower layers. Moreover, since the background rate scales with the detector volume, low energy events collected from the first few layers in the stacked detector have a high signal to background ratio, in comparison with events obtained from a monolithic detector with a thickness equal to the sum of all layers.

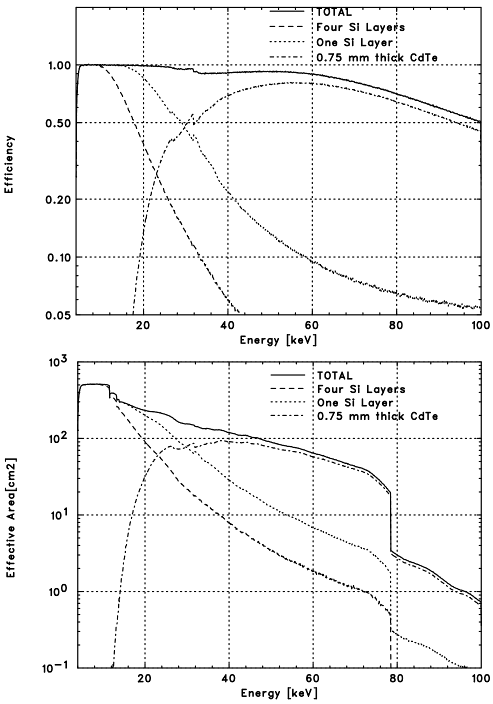

Fig. 2. The HXI detection efficiency (upper) and the effective area of one HXT-HXI system (lower).

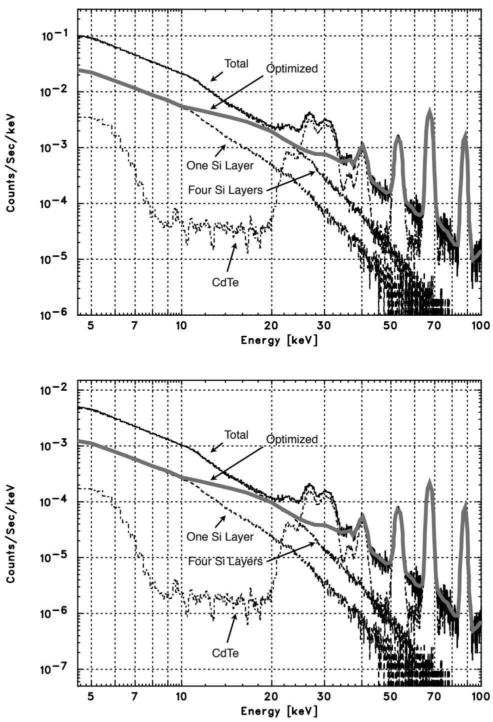

Fig. 3. The expected background spectra for the whole detection area (upper) and for a point source (lower). The orange spectrum shows an optimized background level.