DEVELOPMENT OF SPACEWIRE-BASED DATA ACQUISITION SYSTEM FOR A SEMICONDUCTOR COMPTON CAMERA

Session: SpaceWire Missions and Applications

Short Paper

Hirokazu Odaka, Motohide Kokubun, Shin Watanabe, Shin'ichiro Takeda,
Takeshi Takashima, Tadayuki Takahashi,

*Department of High Energy Astrophysics, Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agnency (JAXA),
3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan*

Takayuki Yuasa, Kazuhiro Nakazawa, Kazuo Makishima,

The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo, Japan

Masaharu Nomachi,

*Laboratory of Nuclear Studies, Graduate School of Science, Osaka University,
1-1 Machikaneyama, Toyonaka, Osaka 560-0043*

Hiroki Hihara,

*NEC TOSHIBA Space Systems, Ltd. ,
10, Nisshin-cho 1-chome, Fuchu, Tokyo 183-8551, Japan*

Takayuki Tohma,

NEC Corporation, 10, Nisshin-cho 1-chome, Fuchu, Tokyo 183-8551, Japan

*E-mail: odaka@astro.isas.jaxa.jp, kokubun@astro.isas.jaxa.jp,
watanabe@astro.isas.jaxa.jp, takeda@astro.isas.jaxa.jp, ttakeshi@stp.isas.jaxa.jp,
takahasi@astro.isas.jaxa.jp, yuasa@amalthea.phys.s.u-tokyo.ac.jp,
nakazawa@phys.s.u-tokyo.ac.jp, maxima@phys.s.u-tokyo.ac.jp,
nomachi@fn.lns.sci.osaka-u.ac.jp, hihara.hiroki@ntspace.jp, t-tohma@bx.jp.nec.com*

ABSTRACT

We have been developing a compact data acquisition system using SpaceWire interface for a semiconductor Compton gamma-ray camera. The system, which is based on our multi-purpose data acquisition framework, consists of a very small computer called SpaceCube and an electric circuit board with SpaceWire interfaces. Adoption of remote memory access protocol (RMAP) allows us simple handling of data. We can operate the detector and read data from the detector by software using RMAP libraries. We apply the system to a balloon-borne experiment which utilize the semiconductor Compton camera as a focal plane detector of hard X-ray imaging optics. In this paper we describe overview of the data acquisition system of the Compton camera based on SpaceWire technology and its application to the balloon-borne experiment.

1 INTRODUCTION

We have developed a semiconductor Compton camera which achieves gamma-ray spectral imaging with high energy resolution and high angular resolution[1]. It is a promising detector for the next-generation astrophysical observation of high energy universe. The camera consists of four double-sided silicon strip detectors (DSSDs) and 32 cadmium telluride (CdTe) pixel detectors (Fig. 1). The DSSDs form into a four-layer stack and the CdTe pixel detectors surround the bottom and horizontal direction of them in order to detect gamma-ray photons scattered at the DSSD part. Since each individual DSSD has 64 strips on each side and each CdTe pixel detector has 8x8 pixels, we have to read out many channels (total 2560 channels). Thus a high-speed and multi-channel data acquisition (DAQ) system is required under limitation of resources on a balloon. For this purpose, we have been developing a new compact DAQ system based on SpaceWire interface (I/F) and remote memory access protocol (RMAP) for a balloon-borne experiment.

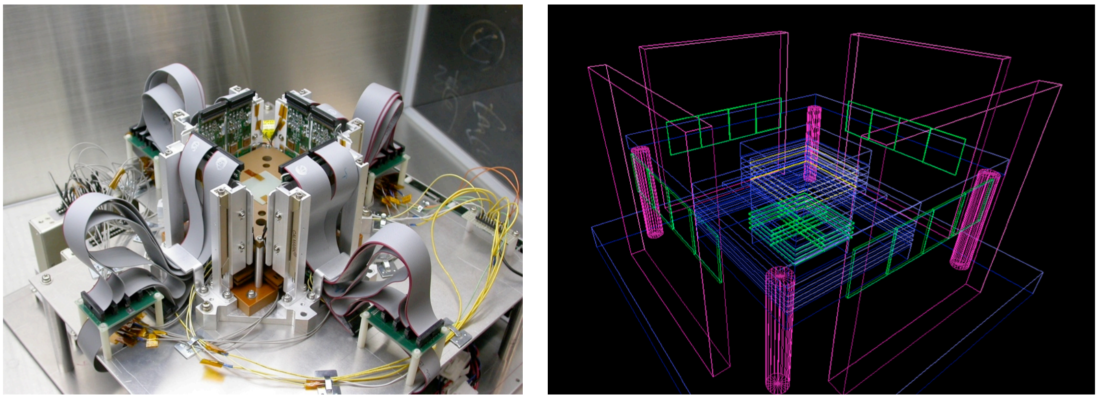

Fig. 1 Left panel: a picture of the Si/CdTe semiconductor Compton camera. Right panel: structure of the Compton camera. Si and CdTe detectors are drawn as yellow line and green line, respectively.

2 DATA ACQUISITION SYSTEM OF SEMICONDUCTOR COMPTON CAMERA

For a data acquisition system of the Compton camera we utilize our SpaceWire-based multi-purpose DAQ framework[2]. The framework includes common functions of data acquisition for scientific detectors, and therefore users of it are allowed focusing on development of application-dependent functions. The DAQ system of Compton camera consists of a very small computer called SpaceCube with SpaceWire I/F (the size of SpaceCube is 52x52x55 mm) and SpaceWire Digital IO board (Fig. 2). The circuit board has digital inputs/outputs (LVCMOS, LVDS), a 16 MB SDRAM for data buffer, two FPGAs (SpaceWire FPGA and User FPGA), and SpaceWire I/F. SpaceWire FPGA has SpaceWire RMAP engine. User FPGA, which connects to digital I/Os and SpaceWire FPGA, can be designed by users for data processing.

Figure 3 illustrates the DAQ system of the Compton camera. The Compton camera is composed of six independent detector modules (two DSSD modules and four CdTe detector modules). Each module has six digital ports (*TrigOut*, *TrigIn*, *Command*, *Command-clock*, *Data*, *Data-clock*) to comunicate with User FPGA on SpaceWire Digital IO board. The structure of User FPGA is based on the DAQ framework, which

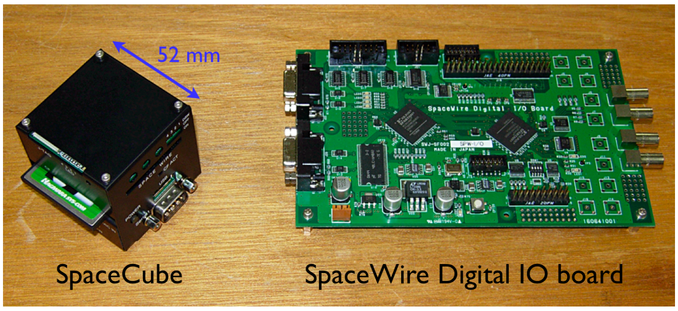

Fig. 2 SpaceCube and SpaceWire Digital IO board

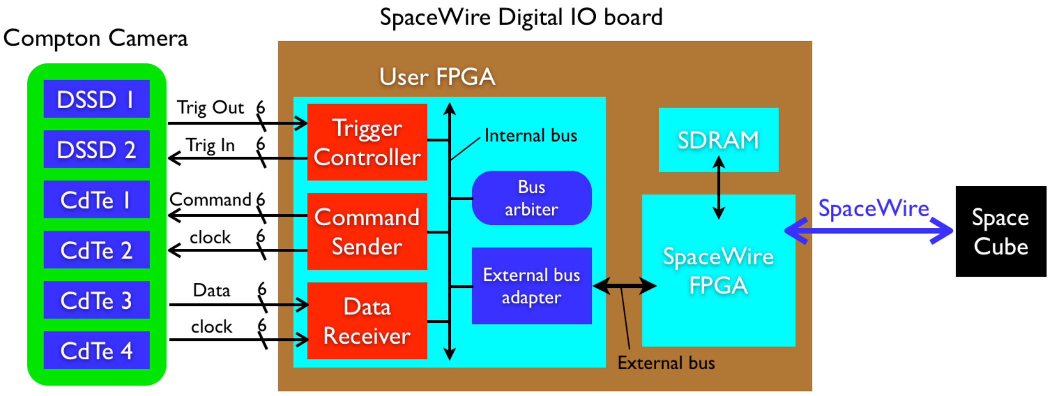

Fig. 3 A block diagram of the DAQ system of the Compton camera. While the DAQ framework offers the internal bus system and the external bus adapter in User FPGA, red modules in User FPGA are user-dependent.

provides modularized internal bus system including its arbiter and the external bus adapter to SpaceWire FPGA.

In User FPGA three user-dependent modules which connect to the internal bus are implemented for data readout from the Compton camera: Trigger Controller, Command Sender, and Data Receiver. The individual detector module composing the Compton camera digitalize signals from the semiconductor detectors by an analog-digital converter (ADC) and outputs serialized bit array via *Data* and *Data-clock* lines. The serialized data consists of the header part (8 bytes) and the data part. The data part structure is array of “4-bit flags + 12-bit ADC value” and its length is equal to the number of channels. The total size of one event data from all the detector modules is 5168 bytes. The data are received by Data Receiver and transfered through the internal bus and external bus to the SDRAM. Since photon-detection events occurs randomly and simultaneous readout from all the detector modules are required, Trigger Controller controls timing of readout via *TrigOut* and *TrigIn* lines. Command Sender sends various commands to the detector modules via *Command* and *Command-clock* lines.

From SpaceCube all modules in User FPGA and the SDRAM can be accessed by RMAP. All operations of the system, for example reading data from the SDRAM, sending commands to the detector, or setting registers of modules in the FPGA, are implemented by using RMAP Read/Write. SpaceCube program which operates the

Compton camera is written in C++ language and uses RMAP library of the DAQ framework.

We expect that the average event rate is less than 100 events per second. Thus required data transfer rate is more than 4 Mbps. Now our system in which SpaceWire IP core beta version is implemented have achieved the data transfer rate of 0.6 Mbps. In order to increase the data rate, we are developing new SpaceWire IP core which transfer data to RAM in SpaceCube by using direct memory access (DMA).

3 HEFT Balloon-borne Experiment

We will perform a balloon-borne experiment with the Compton camera at Australia in 2008 summer. The mission named High Energy Focusing Telescope (HEFT) by California Institute of Technology, Columbia University and ISAS/JAXA is aimed at hard X-ray and soft gamma-ray imaging spectroscopy of high energy universe at 20 - 80 keV. The balloon carries three hard X-ray telescopes; our Compton camera (ISAS detector) is arranged at one of their focal planes.

Figure 4 is a block diagram of the data processing system for the HEFT experiment. The system has three SpaceWire I/F boards connected to SpaceCube via SpaceWire: SpaceWire Digital IO board for data acquisition of the Compton camera, SpaceWire FADC board, which has an ADC and digital I/Os, to read temperature and pressure sensors and to control high-voltage biases of the detectors, SpaceWire Digital IO board for communications (telemetry/command) with the central computer of the balloon system developed by Caltech.

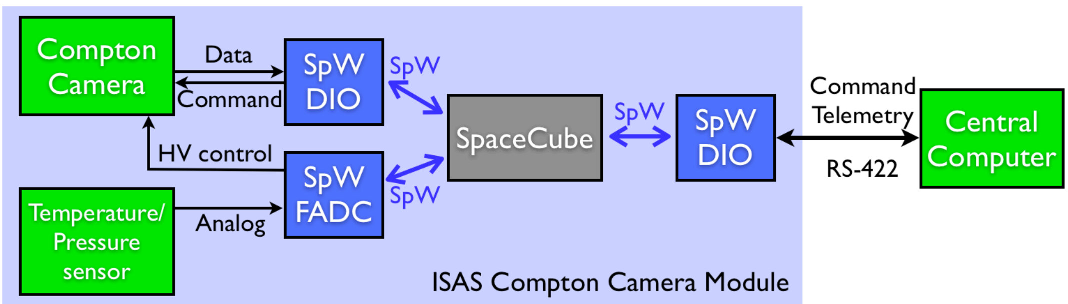

Fig. 4 A block diagram of the HEFT data processing system. There are three SpaceWire I/F boards.

4 References

1. S. Takeda et al., "A new Si/CdTe semiconductor Compton camera developed for high-angular resolution" in "Hard X-Ray and Gamma-Ray Detector Physics IX", Proceeding of SPIE, Vol. 6706, 2007.

2. T. Yuasa et al., "Development of a SpaceWire/RMAP-based Data Acquisition Framework for Scientific Detector Applications", this volume.