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変革を駆動する先端物理・数学プログラム（FoPM）
国外連携機関長期研修　報告書

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Purpose:

We are now proceeding with the solar observation rocket experiment FOXSI (The Focusing Optics X-ray Solar Imager). FOXSI aims to reveal the energetics of solar flares by realizing the direct imaging method, that combines a Wolter-I focusing optics and fine-pitch focal plane detector. FOXSI has been successfully launched three times so far, and In 2024, the fourth flight FOXSI-4 will be launched as the first “flare campaign,” which aims to achieve the photon-counting observation of solar flares by launching a rocket at the same time as the solar flares occur.

Our group is in charge of the development of the hard X-ray focal plane detector (CdTe-DSD: CdTe double-sided strip detector) that will be installed as four out of seven focal plane detectors. The basic performance tests and calibration of CdTe-DSDs are already conducted in IPMU, Japan. However, it is essential to conduct integration tests in the Minnesota U. that combine the detectors with the power supply board and the detector cooling system, which are being developed by Minnesota U. research groups. In addition, the data acquisition system, including how to store the data from the detectors and how to select and send data as telemetry, should be constructed in close consultation with the engineers at Minnesota U. research groups.

Work:

1) Integration test of CdTe-DSDs with Nitrogen cooling system and Power-board.

The four flight detectors + one spare detector were shipped to the University of Minnesota. First, using the spare detector, we cooled it to -20°C using a thermostatic chamber and carefully examined the measurement environment including the power supply noise and grounding condition. We found that the power supply used in Minnesota U has a larger ripple noise. We also found that the environmental chamber act as some noise sources. After improving the condition, we confirmed that data can be acquired at the same low noise level as in the IPMU/Japan test. We also took data with replacing a power supply to the power board for flight developed by Minnesota U. and confirmed that the same performance can be obtained. The spare detector was then placed in the focal plane and cooled to -20°C using nitrogen cooling flow (Fig. 1) to confirm that the expected spectral performance can be obtained. I also visited in U.C. Berkeley and discussed with Hunter Kanniainen, Mechanical Engineer of FOXSI team, about the housing design of FOXSI CdTe-DSDs.

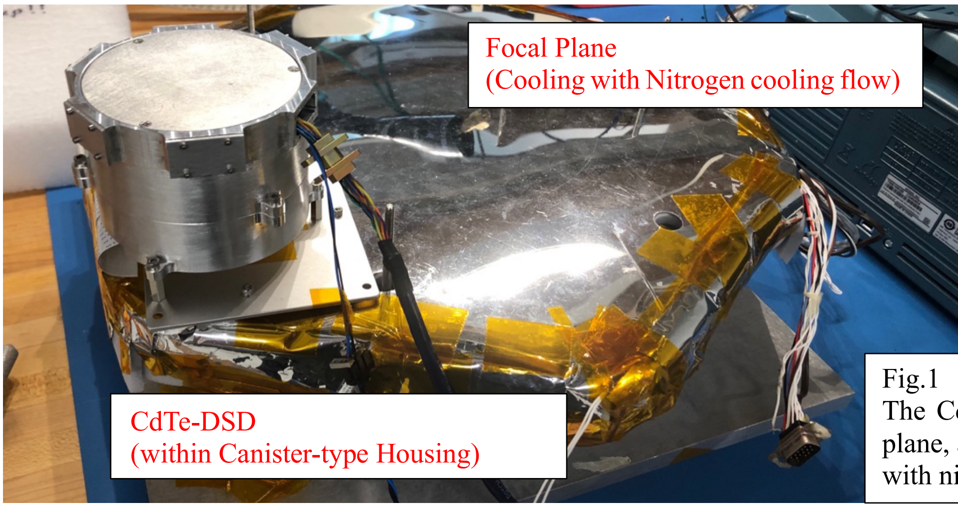

Fig.1
The CdTe-DSD is installed in focal plane, and cooled to -20°C with nitrogen cooling flow

2) Construction of data acquisition system for CdTe-DSD using FPGA board and SpaceWire I/F

Unlike quiet-sun observations for the past three FOXSI launches, FOXSI-4 will be launched at the same time a flare occurs. Therefore, it is necessary to increase the readout rate from the conventional 500 Hz to 5000 Hz, which is required for solar flare photon observation even for the high counting rate of flares. Therefore, we are constructing a new high-speed data acquisition system (Figure 2) by combining the data acquisition board called SPMU-001, which combines 128 Mbytes of DRAM, high-speed data transfer by Gigabit Ethernet, and FPGA, with the SpaceWire interface, which is high-speed space-standard communication interface.

The observation data from the CdTe-DSD is recorded in the DRAM memory on the SPMU and in the SD card on the Raspberry Pi on the CdTe-DE. All the data is stored in the SD card and will be recovered after the launch. As a quick look and as insurance, some important parts of data should be selected and telemetrically transmitted to the ground via Formatter. Currently, Athanasios Pantazides, project manager and engineer at the University of Minnesota, is in charge of the Formatter side and I am in charge of the CdTe-DE side. Therefore, during staying at the University of Minnesota, we have decided on the detailed specifications such as the structure of the memory address map for the Formatter to acquire data and change observation mode/parameter. The CdTe-DE software is controlled by a 64Hz time code clock, and the command pooling from the Formatter is conducted using 4Hz/64Hz, and the data taken from each detector is conducted using 15Hz/64Hz. By writing the 12-byte command to the CdTe-DE address by the Formatter, the observation mode (initialize, setting DAQ/ASIC parameter, data taking etc…) can be controlled. The data from each CdTe-DSD is stored in a ring buffer in CdTe-DE, and the Formatter can take this data by checking the write/read address of the ring buffer. The basic data acquisition system has been constructed, and the data from CdTe-DSD can be successfully obtained. In addition, the communication with CdTe-DE and Formatter using the SpaceWire interface was also successfully conducted.

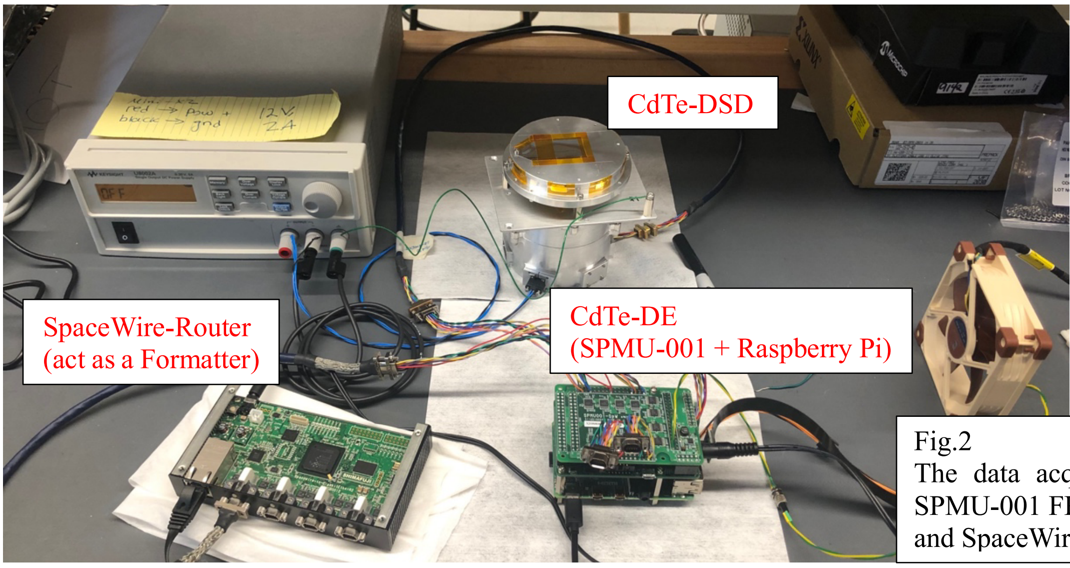

Fig.2
The data acquisition system using SPMU-001 FPGA board and SpaceWire interface

3) Presentation at UMN Space Physics Seminar and the international conference SORMA XIX

During the Minnesota U. visit, I was invited to make a seminar at the Space Physics Seminar about the solar flare data analysis using MinXSS and RHESSI (published in ApJ in 2022). I made a presentation under the title of “Wide-band X-ray spectral analysis with MinXSS and RHESSI” and had a discussion on the physics of thermal/non-thermal emission from solar flares.

Fig.3
SORMA conference dinner at henry ford museum

At the end of the “International Research Experience course,” I participated in SORMA XIX (IEEE Symposium On Radiation Measurements and Application), which is the international conference of the radiation detector at the University of Michigan. I was selected as an oral presenter and made a presentation under the title “Wide-Gap CdTe Double-Sided Strip Detectors for High-Resolution Imaging Spectroscopy of Solar Flares in Hard X-rays.” I presented the spectral and imaging performance of wide-gap CdTe-DSD and had a discussion on response modeling with the professional of detector development. The contents of the presentation also will be published as a proceeding paper in NIMA.