X-ray γ-ray Polarimetry Satellite PolariS

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ABSTRACT

PolariS (Polarimetry Satellite) is a Japanese small satellite mission dedicated to polarimetry of X-ray and γ-ray sources. The aim of the mission is to perform hard X-ray polarimetry of sources brighter than 10 mCrab, employing three X-ray super mirrors and imaging polarimeters. The X-ray polarimetry enables us to study unresolved structure of the universe, for example, magnetic field in the super nova remnants, geometry of accretion disks around black holes. Energy dependence of the polarization degree and direction is essential for such studies, and high degree of polarization is expected for non-thermal emissions. We thus set our target energy range to 10-80 keV, which is complimentary to the soft X-ray polarimetry mission currently considered by various groups. The second purpose of the mission is to measure polarization of gamma-ray bursts (GRBs) with wide field instruments, as was done with IKAROS/GAP. PolariS GRB polarimeters aim to detect 10 GRBs/yr. The satellite design follows the guideline of the JAXA small satellite series, in which common bus system is employed. Target launch date is around 2020. We concisely report the outline of the design of PolariS and recent experimental results using a proto-model of hard X-ray polarimeters for PolariS.

KEY WORDS: X-ray polarimetry: small satellite: PolariS

1. PolariS Design and Components

PolariS carries three hard X-ray telescopes with a focal length of 6 m. Those telescopes are installed on an extensible optical bench (EOB). On the focal plane of each telescope, a hard X-ray imaging polarimeter is installed. The hard X-ray telescope employs multilayer coated super mirrors as for the hard X-ray telescope (HXT) for ASTRO-H. In addition to the difference in the focal length of the telescope, 6 m for PolariS 12 m for ASTRO-H, the inner and outer diameter of the telescope will be reduced from the ASTRO-H original design. The design of the EOB follows the ASTRO-H design with its length. In addition to these telescope system, wide field γ-ray polarimeters to detect GRB polarization are installed.

The satellite was originally designed as one of the JAXA small satellite series. The satellites in this series consists of a common bus system with necessary customization and various mission components on it. The bus system is 1 m³ cubic in size and weights 260 kg (in
the case of PolariS), while the mission part including the EOB and base plate for it weight 187 kg. The power consumption of the mission components is evaluated to be 106 W. The satellite will take a typical low earth orbit, altitude of about 550 km and the inclination of about 30°. The telescopes are aligned and directed to the target source by the 3 axis attitude control system with accuracy of 1 arcmin. The satellite will be rotated around the telescope axis to minimize possible systematics for polarization direction and degrees. The rotation speed will be 0.1 RPM so that the variation of non-X-ray background should not be significant during one rotation.

Preliminary report of the satellite design is given in Hayashida et al. (2010), Hayashida et al. (2012), in which one of the three telescopes was dedicated for a soft X-ray polarimeter. We changed the design of PolariS so that all the three telescopes are for hard X-ray polarimetry.

2. Hard X-ray Imaging Polarimeters

We have developed Scattering type Imaging Polarimeters (SIP) to install on the focal plane of the PolariS hard X-ray telescopes. The SIP is a scattering type polarimeter, which employs the anisotropy of scattered direction of X-ray photons as a working principle. Proto-type of this polarimeter is the polarimeter for the PHENEX balloon experiment (Kishimoto et al. 2007), in which segmented scintillators and MAPMT are used, although the SIP for PolariS has different configuration so as to be optimized as satellite-use, focal-plane imaging polarimeters. Nine MAPMTs are used for one unit of the (flight model) PolariS polarimeter; plastic scintillator pillars are placed on one MAPMT placed at the center, while absorber GSO scintillators pillars are placed on surrounding 8 MAPMTs. When an X-ray photon incident to a plastic scintillator pillar causes a Compton scattering, recoiled-electron energy is deposit in the scintillator. Furthermore, if the scattered X-ray photon is absorbed in a GSO pillar, the incident position and the scattered direction can be measured for this event.

In the proto-model SIP, we employed one unit of H7546B-200 and 4 units of H8711-200, as the MAPMTs. Plastic scintillator pillars each of 2.1x2.1x40mm are assembled in 8×8 and placed on the former. This covers imaging area of 18mm×18mm (10’×10’). GSO pillars each of 4.3×4.3×60mm are assembled in 4×4 and placed on the latter.

2.1. Performance Test at Synchrotron Facility

We irradiated monochromatic polarized X-ray beam in the energy range of 10-80 keV at the synchrotron facility, KEK PF BL14A. Fig. 1 shows the summary of the results in two kinds of operation modes. The modulation factor \( M \) is as larger as 50% to 60%, one of the highest among hard X-ray polarimeters under development. We also succeeded in obtaining an efficiency \( \eta \) of about 2% at 20 keV incidence in the double hit mode, in which plastic scintillator signal is detected.

References

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Fig. 1. Modulation Factor \( M \) and the Detection Efficiency \( \eta \) of the PolariS SIP proto-model. Closed marks represent the measured data, while open marks represent simulation for them. Note that the SIP proto-model has only 4 surrounding units, and we expect factor 2 improvement for flight model in which 8 surrounding units will be employed.