Alignment adjustment with Micro-actuators for Lobster eye optics abord HiZ-GUNDAM satellite

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Abstract

HiZ-GUNDAM is a satellite designed to observe gamma-ray bursts (GRBs), which are among the largest explosive phenomena in the universe, and aims to explore the early cosmic environment. The EAGLE (Wide-Field X-ray Monitor) onboard this satellite collects X-rays using Lobster eye optics and detects them using a focal plane image sensor as pnCCD. Lobster eye optics realizes a wide field of view by arranging multiple Lobster eye-type micropore optics (MPO) spherically. However, due to distortions and focal length variations in MPOs during manufacturing, simply arranging them randomly causes variability in the focal positions. Therefore, it is necessary to select MPOs with similar properties so that the imaging positions coincide and adjust the attaching angles through alignment procedures. In this session, focusing on differences in radii of curvature and angular response, we selected four MPOs and adjusted alignment using actuators mechanisms.

HiZ-GUNDAM

High-z Gamma-ray bursts for Unraveling the Dark Ages Mission

Key Science

Early Space Exploration and **Multi messenger astronomy**

- ➢Generation rate of z>7 GRBs
- ➢Ionization status
- ➢History of heavy atom composition
- ➢Observe the Pop-III GRBs
- ➢High energy physical phenomena with Gravity wave and Neutrino
- ➢Detect stars of releasing electromagnetic wave
- ➢Dissipation process of gravity energy
- ➢Connection of NIR, Optical, and X-ray

Gamma-Ray Bursts(GRBs)

GRBs are Known as one of the brightest explosion in the universe

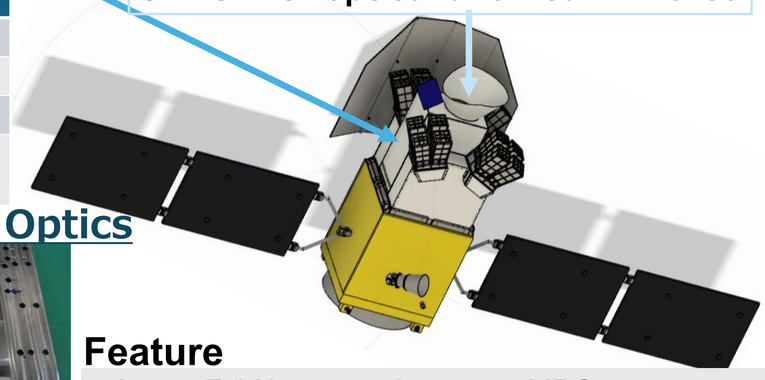
EAGLE(Wide Field X-ray Monitor)

Detect and localize GRBs with soft-X-ray

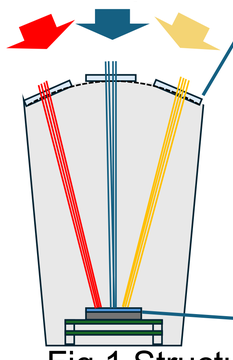
MONSTER(Optical and Near-infrared Telescope)

Follow-up observation of detected GRBs with optical and near-infrared

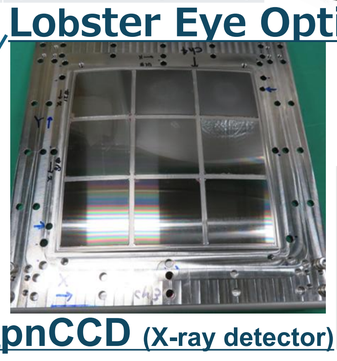
Table1 Science goal	
Energy Band	0.4~4.0 keV
Position Accuracy	1.5 arcmin (1σ)
Field of View (FoV)	0.53 sr
Sensitivity	$\sim 10^{-10}$ erg/cm^2/s (for 100s exposure)



X-ray



Lobster Eye Optics



pnCCD (X-ray detector)

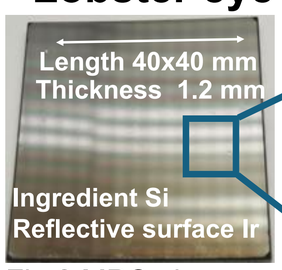
Fig.1 Structure of EAGLE

Feature

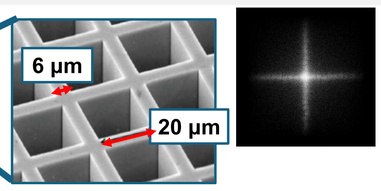
- ➢Large FoV by arranging many MPOs on a spherical surface(Fig.1)
- ➢Focus soft X-ray($10^{2\sim3}$eV)(Fig.2)
- ➢Concentrating the X-ray signal suppresses background and enables high sensitivity.(Fig.3)

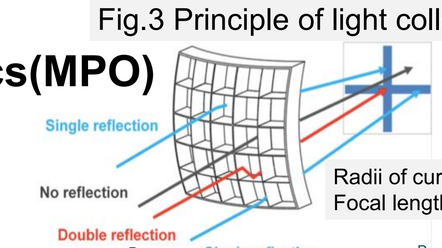
Fig.3 Principle of light collection

Lobster eye type Micro pore optics(MPO)



Radii of curvature ~ 600 mm





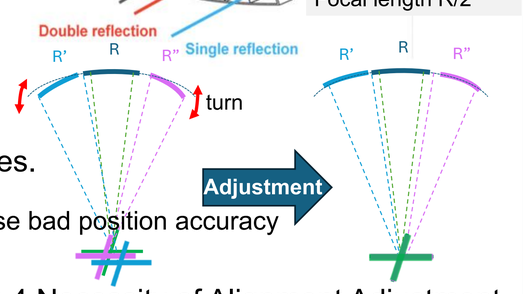


Fig.2 MPOs has a curved surface with many micro pores. X-ray is focused into a cross-shaped pattern.

Alignment adjustment is required because of the individual variations among MPOs.(Fig.4)

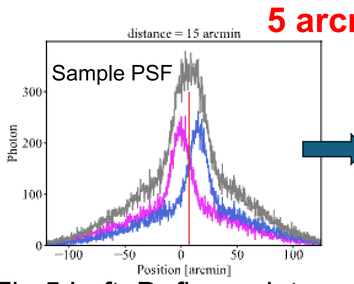
Fig.4 Necessity of Alignment Adjustment

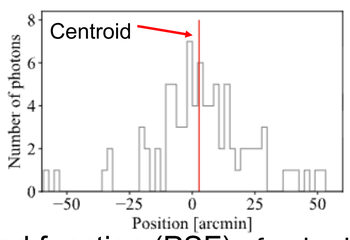
The goal of alignment accuracy

Although our final goal is 1.5 arcmin (Table 1), as a first step we set an experimental goal that can achieve 2 arcmin for 1000 photons.

Set goal of Alignment accuracy

5 arcmin from Fig.5





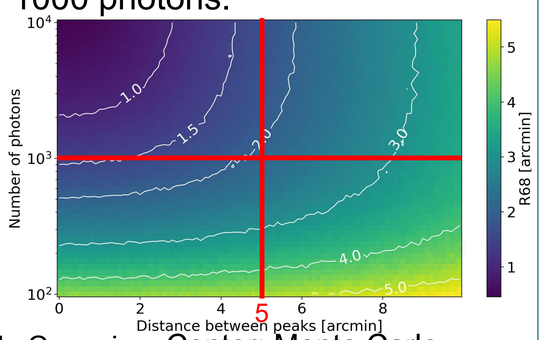


Fig.5 Left: Define point spread function (PSF) of a double Gaussian. Center: Monte Carlo simulations, calculate centroid of 100 photons drawn from the PSF and examine the distribution. Right: the range that contains 68% of the centroid distribution (R68) for different peak separations and photon counts

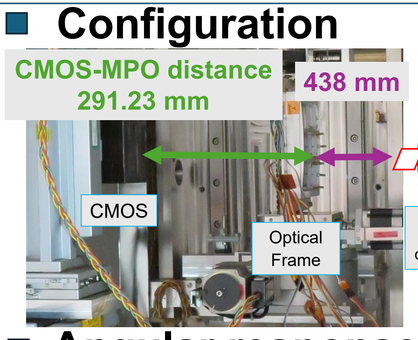
Goto et at (submitted to JATIS)

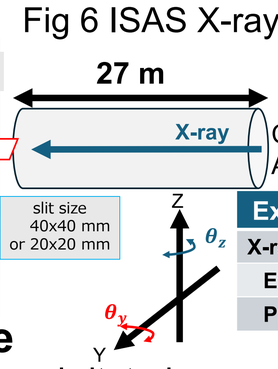
Work in this study

- ➢We selected a combination of 4 MPOs to be able to achieve alignment accuracy < 5 arcmin by measuring MPOs' angular response.(Fig.6)
- ➢We aligned four MPOs using micro-actuators, and verified the reproducibility of the alignment before and after MPO fixation.

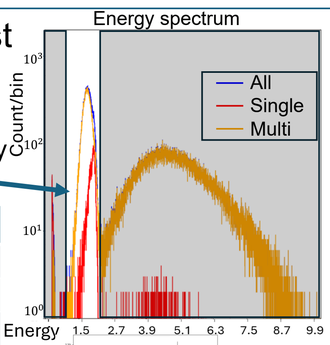
Configuration

Fig 6 ISAS X-ray beam line test





Characteristic X-ray
Al 1.5 keV



Experiment status	
X-ray Target	Al
Exposure	20 ms
Pressure	$\sim 10^{-3}$Pa

Angular response

①40 x 40 mm X-ray beam was irritated around MPOs at 10 arcmin pitches, perpendicular to the optical surface.(Fig.7:l)

②Plot the cross center by fitting gaussian to X,Y projection.(Fig 7:r)

③Select 4 MPOs with similar characteristics such as edge length and internal angle

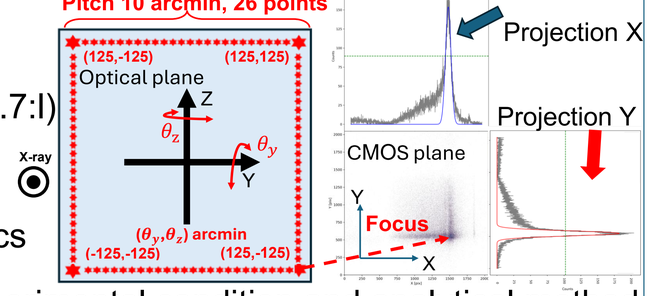


Fig 7 Experimental condition and analytical method

Actuator

Adjustment Time	
Manually	~1.5 day
Micro-actuator	~30 s

Speck	
Maximum range	4 mm
Resolution	0.24 μm/pulse

Fig.8 Actuator's length can be adjusted freely by sending pulses from a PC

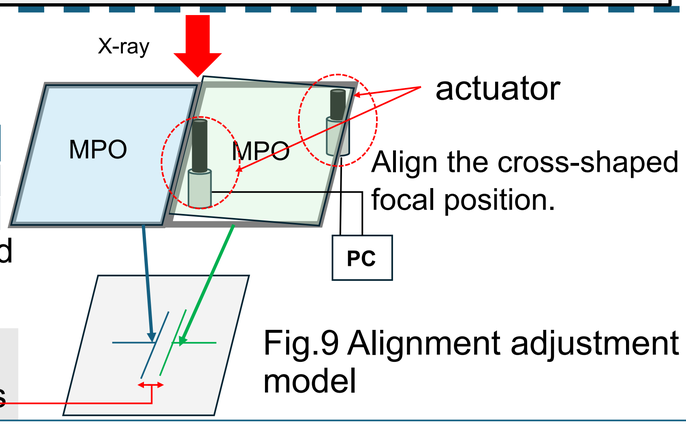
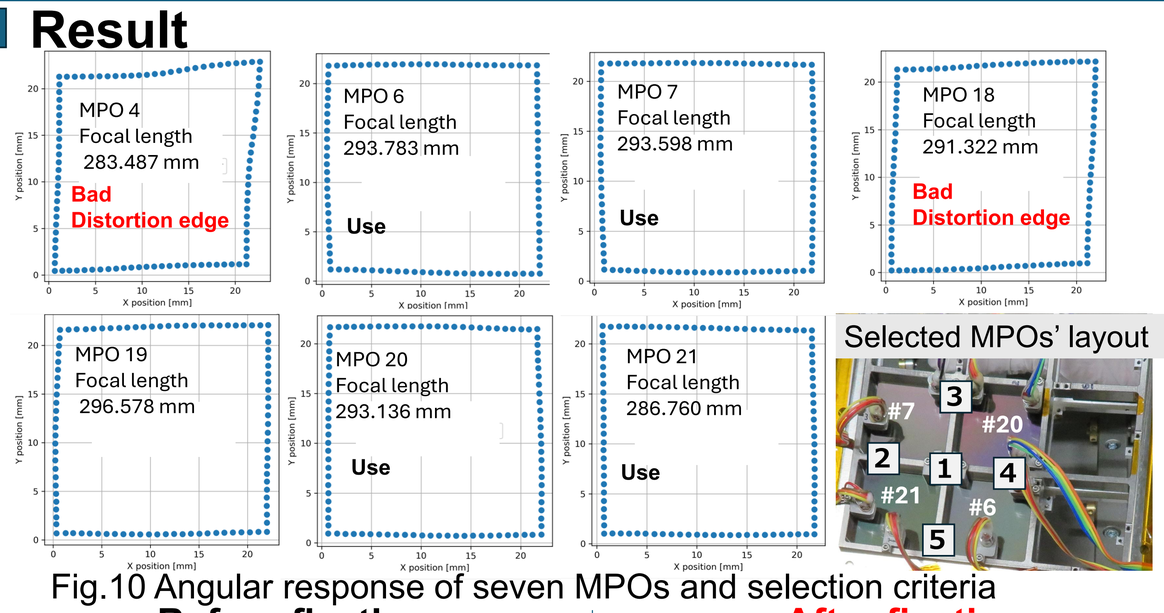


Fig.9 Alignment adjustment model

Alignment accuracy

Difference between two cross centers

Result



Selected MPOs' layout

Fig.10 Angular response of seven MPOs and selection criteria

Before fixation **After fixation**

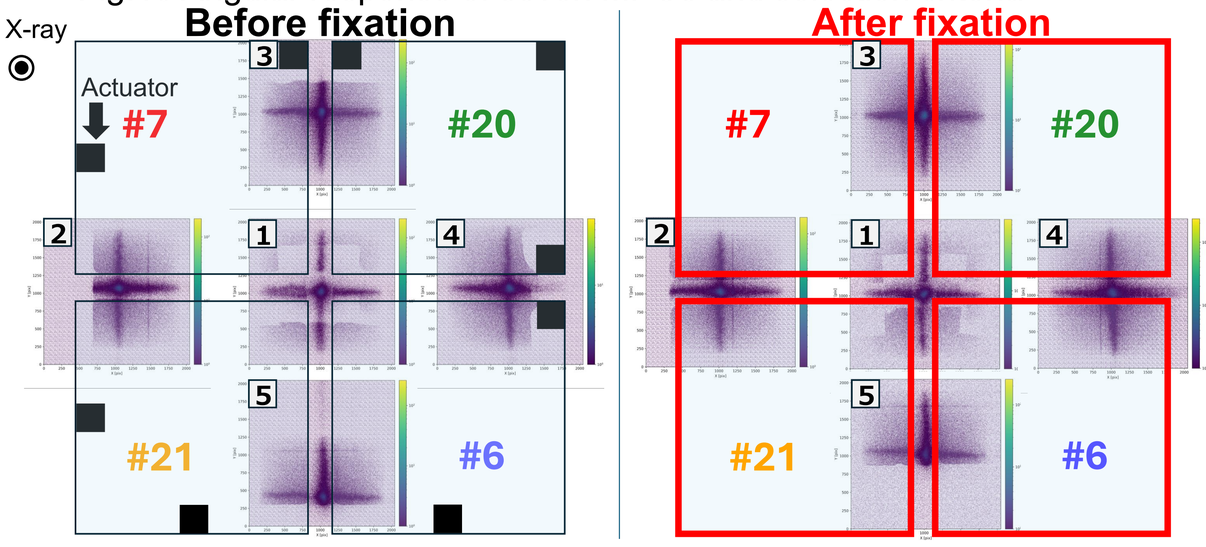


Fig.11 After performing the alignment adjustment in the configuration shown in Fig. 10, we measured alignment accuracy at 5 points

After fixation

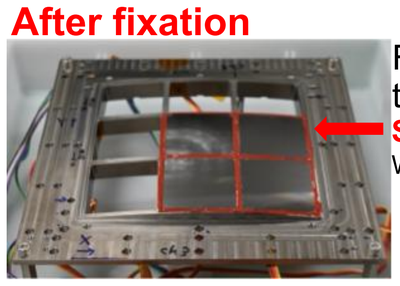


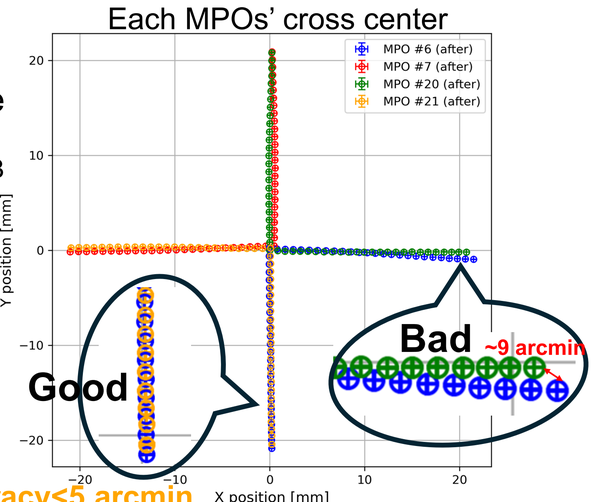
Fig.12 MPOs fixed to the optical frame

Si rubber adhesive

WACKER RTV-S 691 A/B

Fig.13 The alignment accuracy over the entire field was estimated using the results of angular response and alignment measurements at 5 points

Each MPOs' cross center



Ratio of alignment accuracy<5 arcmin

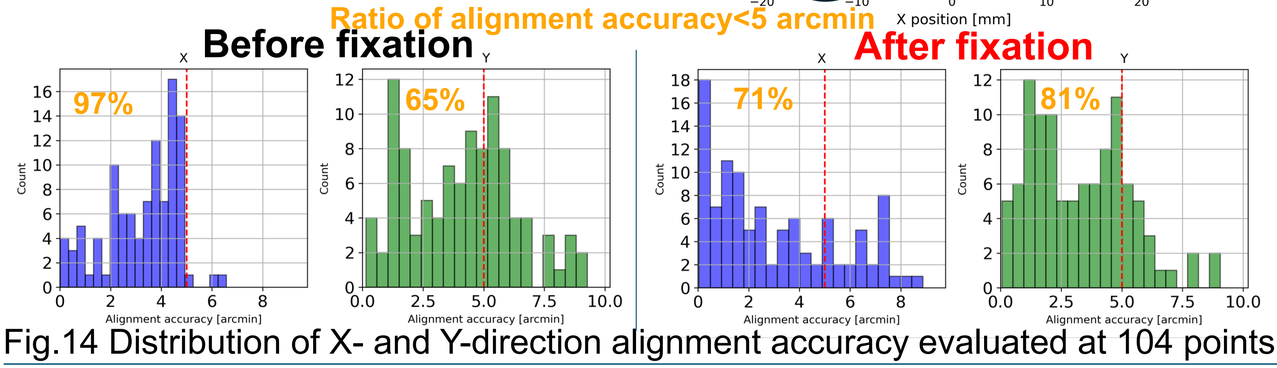


Fig.14 Distribution of X- and Y-direction alignment accuracy evaluated at 104 points

Discussion

- ➢Some MPOs exhibit deformation, which degrades the alignment accuracy.
  - ・MPOs should be arranged to compensate for deformation.(Fig.10)
- ➢Some points show alignment errors significantly larger than 5 arcmin.(Fig.13)
  - ・Local distortions within a single MPO degrade the alignment accuracy.
- ➢The alignment accuracy changed before and after fixation.(Fig.11 & 14)
  - ・The alignment accuracy before fixation should be improved.

Conclusion

- ➢After measuring the angular response of the MPO, alignment adjustment was performed using actuators.(Fig.8 & 9 & 11)
- ➢ Fixation of the MPO caused a small shift in alignment.

Future work

- ➢Identify fixing techniques that minimize alignment deviation.
- ➢Complete the alignment of 9 MPOs.