Demonstration of multiplexing lobster-eye optics

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Wide-field X-ray monitor is essential in astronomy to catch short-time events, such as gamma-ray bursts,[1)] and neutron-star mergers.[2)] The all-sky X-ray monitor, MAXI,[3)] which we have operated on the ISS since 2009, has proven its usefulness. As an extension of MAXI to the soft X-ray band and precise-imaging, we introduced the multiplexing lobster-eye (MuLE) optics.[4)] we have recently performed verification experiments of MuLE for the first time. In this report, we present the angular resolution of MuLE obtained with Ti Kα (4.5 keV) X-rays.

The test setup is shown in Fig. 1. We used micro porous optics (MPOs) made by NNVT company with $R = 750$ mm and the size of 43 mm square. The CMOS image sensor was Gpixel 400BSI-TVISB, whose size was 22.5 mm square. X-rays through the three MPOs focus on a single CMOS placed on the focal plane at a radius of $R/2$, where R was the curvature of MPO. The field-of-view of a mirror is 3 deg $\times$ $\pm$1.5 deg. Each mirror was centered at 0 deg, 9 deg and 18 deg like stepping stones. We added the other side at -9 deg and -18 deg to make one unit. Using 3 units, the whole $\pm$20 deg $\times$ $\pm$1.5 deg sky can be covered. This CMOS has a good energy resolution. We measured the energy resolution of the CMOS for Ti Kα to be $\Delta E/E = 3.7\%$ (FWHM) with single-pixel events at room temperature.

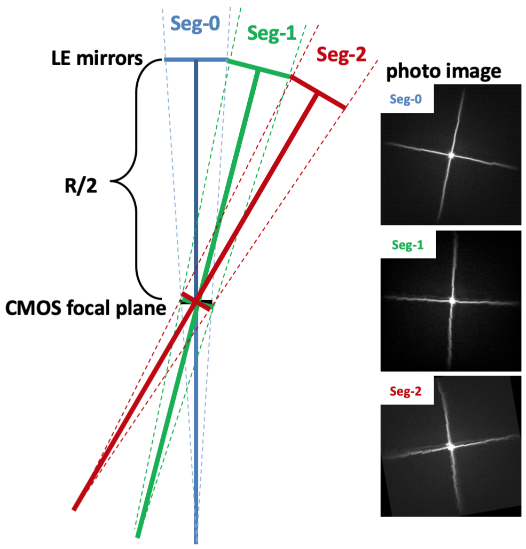

Fig. 1. MuLE experiment and X-ray images of three LE. The brightness corresponds to X-ray intensity.

We showed the focus images in Fig. 1 right. The distance of the Ti X-ray generator to the MPO was 3.85 m. The focal length was measured as 345 mm for this diverging light. In our experiment, the CMOS was set in this distance. Focal length for the parallel light was calculated to be 379 mm. It is close to the designed value (375 mm).

2 MPOs were placed on a mount, and measured Seg-0 and Seg-1 first. The Seg-0 mirror was rotated clockwise around the optical axis by 10 deg, while Seg-1 was 0 deg upright. The direction of the cross arm identifies the MPO which the X-ray comes from. After we measured Seg-0 and Seg-1 we moved the whole mount so that the Seg-1 MPO can locate Seg-2. Then we measured Seg-2. Although Seg-1 and Seg-2 are the same MPO, the image of the Seg-2 was rotated anticlockwise by 10 deg in Fig. 1 for understanding.

A demerit of the MuLE is that the CMOS is placed in a slanted way for the Seg-1 and Seg-2, which makes the image worse in the X direction in our setting.

By fitting the peak of the core in the image, the width of the focus can be measured. The angular resolution (σ) was shown in Fig. 2. It distributed between 4 arcmin to 8 arcmin, which is acceptable. Some jumping data points are due to irregularities on the LE surface.

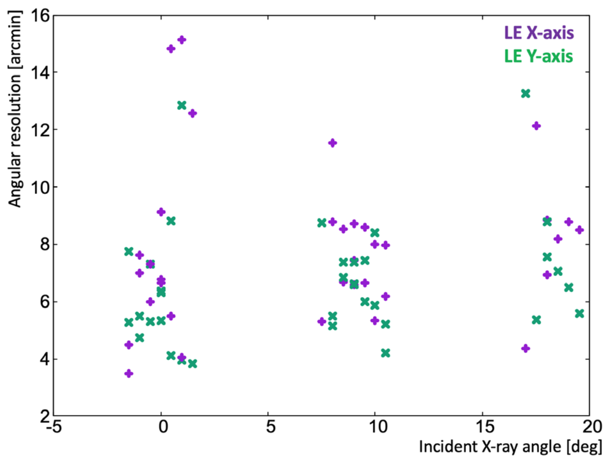

Fig. 2. Incident X-ray angle and position resolution (σ).

This report demonstrated the MuLE system worked as expected. MuLE system can be used in small satellites or ISS payloads to compensate for the soft X-ray performance of MAXI.

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