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High Resolution Optics & Detector Systems for Hard X-rays

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Abstract. We describe the development of hard X-ray focusing optics telescopes at the National Space Science and Technology Center.

1. Introduction

High resolution grazing incidence optics has revolutionized our understanding of the universe in soft X-rays (<10 keV), as illustrated by the exciting results from the *Chandra X-ray Observatory*. The hard X-ray energy band still remains relatively unexplored at fine angular scales due to the lack of such technology. Recent successful test flight (Ramsey et al. 2002) of the high spatial resolution and high sensitivity HERO (High Energy Replicated Optics) payload has initiated a new era in hard X-ray astronomy.

2. New Developments

The Marshall Space Flight Center X-ray group at the NSSTC has an active program of design, development and fabrication of replicated optics for hard X-ray telescopes. The fabrication process involves generating super-polished mandrels, mirror shell electroforming, and mirror testing. These mandrels are precision ground to within ~ 1 μm straightness along each conical segment and then lapped and polished to < 0.5 μm straightness. Each mandrel segment is then super-polished to an average surface roughness of ~ 4 Å rms. By mirror shell replication, this combination of good figure and low surface roughness has enabled us to achieve $15''$ resolution in mirror shells (Ramsey et al. 2003).

Currently, the focal plane detector for each mirror module is a high-pressure gas scintillation proportional counter (Gubarev et al. 2004) with spatial resolution of $\sim$ 400 μm. However, the HERO optics with a focal spot diameter of around 430 μm for a 6-m focal length would require a spatial resolution of around 200 μm to lead to a resolution of $15''$. To match this resolution, we are developing fine pixel CdZnTe detectors, each consisting of a CdZnTe crystal bonded to an ASIC readout chip. Our current detectors have a 16×16 pixel array. We are evaluating two types of ASICs: (a) an ASIC developed by Rutherford Appleton Laboratory, Oxford, England (RAL), which has preamplifiers for each pixel that output to two other integrated circuits for shaping and peak detection; and (b) an ASIC developed at the University of California, Riverside (UCR) which has an preamplifier, shaper, and peak detector for each pixel on the same integrated circuit. The RAL detectors have pixel pad size of 250 μm

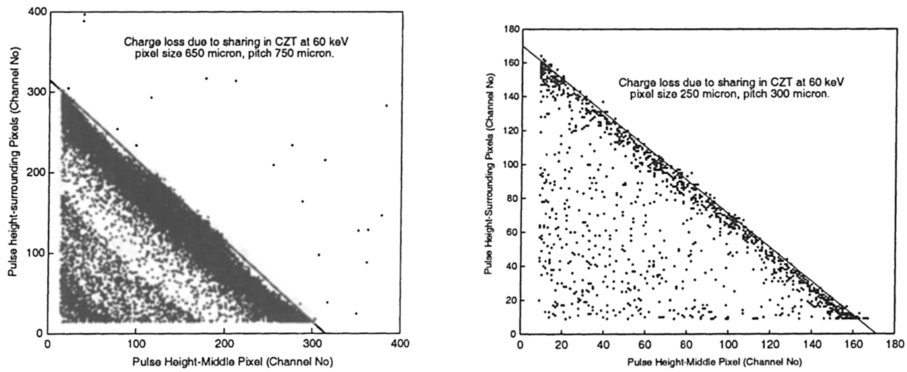

Figure 1. The left panel shows events from a central pixel plotted against shared shared events from the four nearest surrounding pixels for a CdZnTe detector with 750 μm pixel spacing. The bow shape of the response is due to charge loss in shared events. The right panel is for a detector with 300 μm pixel spacing, which shows negligible charge loss in shared events (Sharma et al. 2002).

with a pitch of 300 μm whereas the UCR detectors have a pixel pad size of 225 μm and a pitch of 300 μm. We are studying energy resolutions and spatial resolution achievable, as well as charge loss and charge sharing between multiple pixels. Our current evaluation program is aimed to lead us to the design and development of a 64×64 pixel array detector.

Charge sharing occurs when charge diffuses into adjacent pixels. The effect depends on the pixel pitch and the amount the charge cloud spreads as it drifts towards the anodes. We have measured this diffusion width to be around 42 μm, and, for our 300-μm-pitch devices, this gives sharing of $\sim$ 50% at 60 keV with a 2.5 keV threshold (the noise threshold plays a key role, as it sets the minimum measurable amount of shared charge). The down side of charge sharing is that the output of multiple pixels must be added to recover the full charge, leading to an increase in the electronic noise and hence a worsening of the energy resolution. A benefit of sharing, however, is that it permits position interpolation which can provide better than pixel-pitch resolution (Gaskin et al. 2004).

Measured charge loss can be either due to a real loss of charge during collection, or an apparent loss due to shared charge being below the noise threshold. The former occurs mainly between pixels where the electric field is low. It is particularly noticeable in devices with a large inter-pixel gap. The latter occurs during sharing, and is simply dependent on the noise level on each pixel.

References

Gaskin, J. A. et al. 2004, Proc. SPIE 5165, 45

Gubarev, M. V. et al. 2004, Proc. SPIE, 5165, 151

Ramsey, B. D. et al. 2002, ApJ, 568, 432

Ramsey, B. D. et al. 2003, Proc. SPIE, 5168, 129

Sharma, D. et al. 2002, Proc. SPIE, 4851, 1019

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