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Charge Spreading in Back Illuminated CCD

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A cloud of electrons generated by an incident X-ray in a CCD are dispersed, while they travel to electrodes on the CCD surface. If these electrons spread out of a CCD pixel, the image taken with the CCD is blurred.

We investigated the charge spreading in a commercial-based back-illuminated CCD device developed by Marconi Applied Technologies (MAT): CCD42-40, by utilizing beam lines located at UVSOR Facility in Okazaki National Research Institute and Photon Factory in High Energy Accelerator Research Organization. The same type of the CCD will be used for the X-ray Telescope (XRT) abroad the Solar-B satellite, which will be launched in summer of 2005.

In order to obtain the CCD spatial response with sub-pixel resolution, we used the mesh technique[1]. We prepared a copper mesh whose pinhole is 4μm in diameter, and whose pitch length is twice larger than the CCD pixel size (13.5μm). Just in front of a test CCD, we put the mesh, and rotated it by a few degree around the normal of the CCD surface. The moire pattern clearly appears in raw images (Fig.1). Because of its geometrical regularity, it is easy to derive the relative position of each pixels from pinholes of the mesh. Figure 2 shows the intensity distribution based on the mesh coordinates. The electrons generated by X-ray photons passing through a pinhole located at (1.5, 1.5) spread out of a pixel (bashed box). The modulation pattern is blurred not only by the charge spreading in a CCD but also by the diffraction of a pinhole. We, therefore, subtracted the effect of the diffraction. We approximated the distribution of the charge spreading in CCD 42-40 by a Gaussian function, and then plotted its standard deviation as a function of the absorption depth in silicon at the measured wavelengths (Fig. 3). Because X-ray photons with the shorter wavelength penetrate closer to the electrodes at the front surface, we expected that the shorter wavelength made the smaller spreading size. However, we also expected that the dependence of the spreading size on the absorption depth might be small, because most of X-ray photons are absorbed near the back surface even in the case of the shorter wavelength. In fact, Figure 3 shows the size is almost constant around 0.5 pixel (6.25μm), except for the data at 100A. The constant spreading size may be a general character of back-illuminated CCDs.

As a practical point of view, this experiment shows that the charge spreading in MAT CCD42-40 is one of the primary factors for the image blurring. In fact, we have to pay attention to the charge spreading as well as the optical aberrations and the spacecraft jitter, to evaluate the spatial resolution of XRT.

We would like to thank Prof. Tsunemi and his colleagues of Osaka University for supporting this experiment based on their mesh technique.

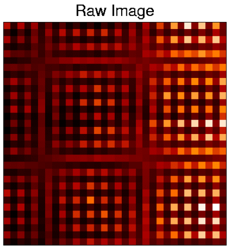

Figure 1: A part of a raw image, which shows the clear moire pattern produced by pinholes of the mesh and CCD pixels.

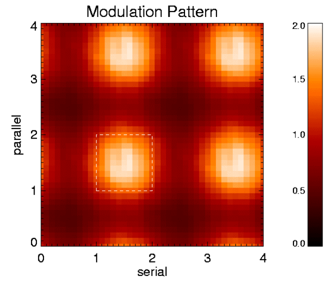

Figure 2: The normalized intensity distribution shown on the mesh coordinated. Pinholes are located at (1.5, 1.5), (1.5, 3.5), (3.5, 1.5) and (3.5, 3.5).

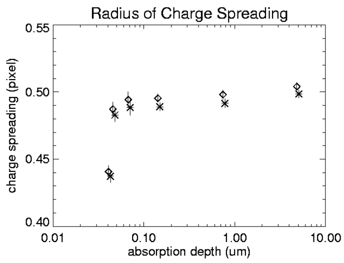

Figure 3: The standard deviation of the charge spreading in CCD42-40 along the serial (stars) and parallel (diamonds) resistors, as a function of the absorption depth in silicon. The data points correspond to the measured wavelengths; 100, 80, 60, 40, 20 and 10 A from the left.

References

[1] Tsunemi et al., Jpn. J. Appl. Phys. 36, 2906 (1997)

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