Laboratory Experiments for the Development of the Multi Image X-ray Interferometer Modules

大阪大学 OSAKA UNIVERSITY

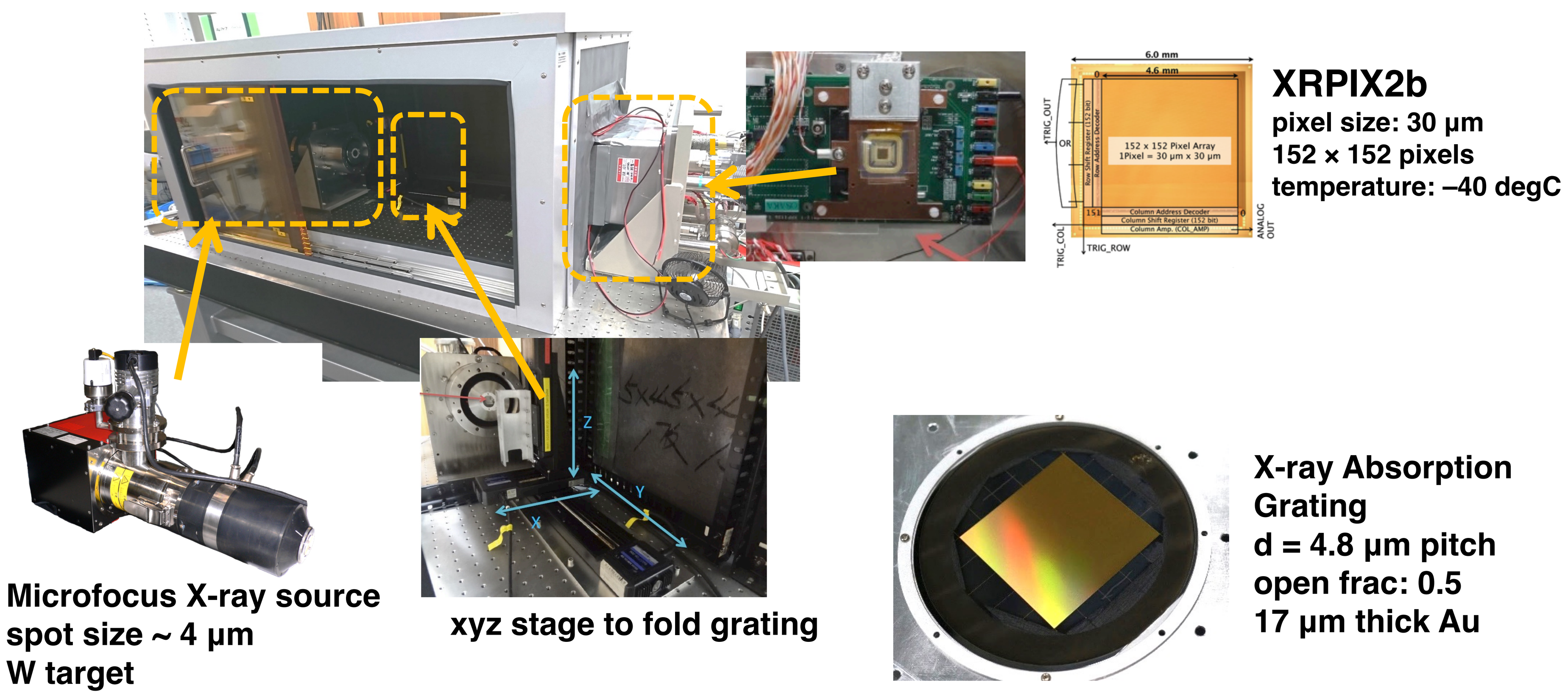
○Tomoki Kawabata[1], Kiyoshi Hayashida[1], Takashi Hanasaka[1], Hiroshi Nakajima[1], Ryo Hosono[2], Takayoshi Shimura[2], Hiroyuki Kurubi[1], Shota Inoue[1], Hiroshi Tsunemi[1], Hironori Matsumoto[1]

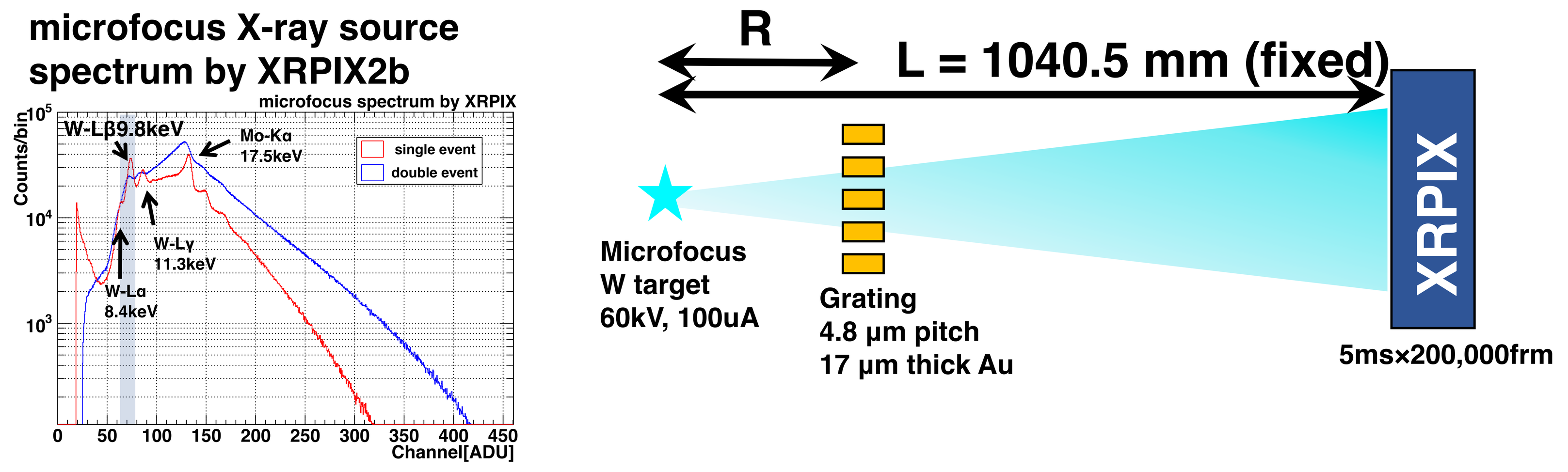
[1]Osaka Univ. of Science
[2]Osaka Univ. of Engineering

We propose a new type of astronomical X-ray interferometer consisting simply with a grating a pixel detector. We started an experiment in our laboratory using a microfocus X-ray source, 4.8 μm pitch 17 μm thick Au X-ray absorption grating, and a XRPIX2b detector with a pixel size of 30 μm. We employ the charge sharing analysis to obtain sub-pixel positional resolution and detected the interference fringes with a magnification factor of 4.4. Our final goal is, however, parallel X-rays from celestial objects, and thus detectors with finer or comparable position resolution as the grating pitch is required. To meet this requirement, we have recently introduce a CMOS sensor GSENSE5130 developed by Gpixel inc. with a small pixel size of 4.25 μm. This device is designed for visible light application, but we find it is sensitive to X-rays. Energy resolution of about 240eV@5.9keV at room temperature is obtained. We present the current status of these preliminary experiments in our laboratory for MIXIM.

Experiment a SOI CMOS detector: XRPIX2b

Microfocus X-ray source + 4.8μm pitch Grating + 30μm pixel XRPIX2b

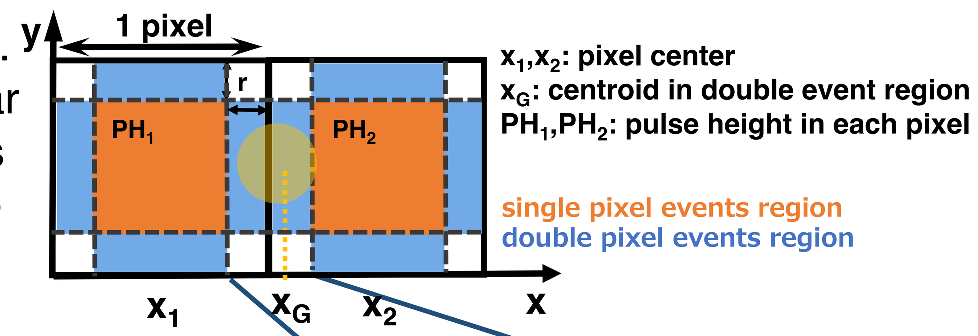




The period of X-ray Talbot interference fringes @R = 235 mm is expected to be 0.7 pixel (21 μm). To obtain sub-pixel resolution, we employ the charge sharing analysis.

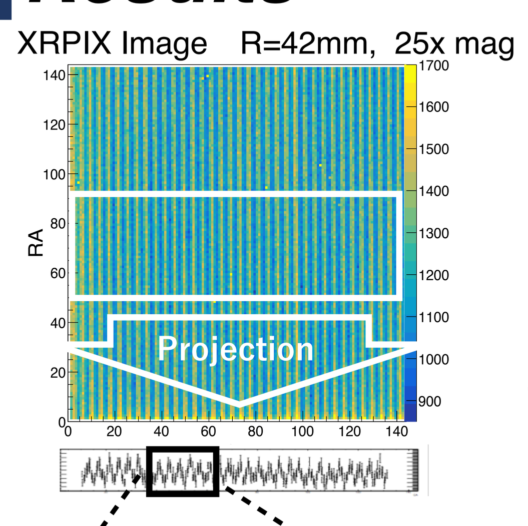
Charge Sharing Analysis for Sub-pix resolution

We detect each event of X-ray photons. When an X-ray photon is absorbed near the boundary of two pixels, the charges generated by the X-ray event spread to two adjacent pixels. The signals from those two pixels can be used for sub-pixel resolution. In our case, the area ratio of the orange region and the blue region (the parameter r) is determined by a counting rate of single pixel events and double pixel events.



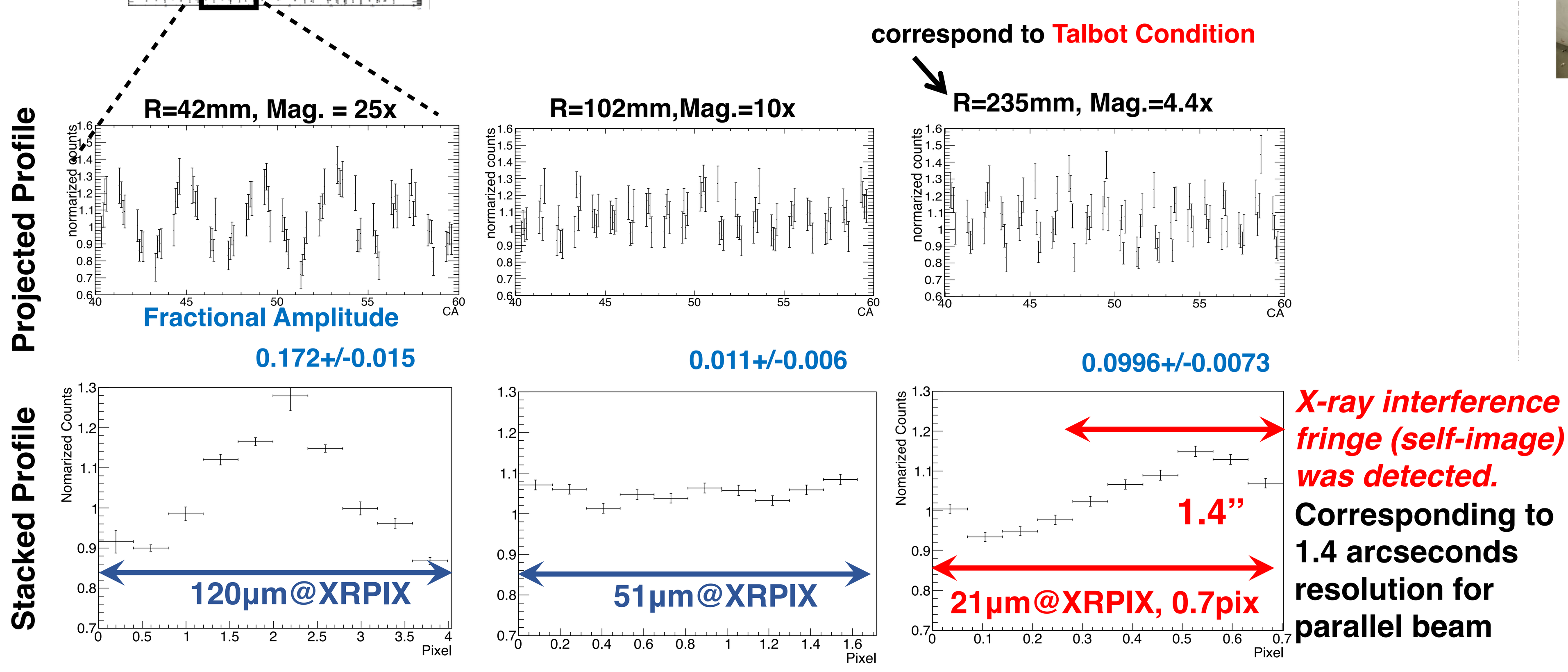
$$x_G = \frac{PH_1\left(\frac{x_1+x_2}{2} - r\right) + PH_2\left(\frac{x_1+x_2}{2} + r\right)}{PH_1 + PH_2}$$

Results



We used the W-Lβ emission line (9.8 keV) for analysis. We selected the X-ray events of which PH= 65 ch to 80 ch, corresponding to 8.8 keV to 10.8 keV. The distance from the source to grating is set at R=42mm, 102mm, and 235mm. R=235mm is the distance with which the Talbot interference condition is satisfied.

Talbot Distance for a Spherical Wave $z_T = \frac{L}{2}\left(1 - \sqrt{1 - \frac{4md^2}{\lambda L}}\right)$



X-ray interference fringe (self-image) was detected. Corresponding to 1.4 arcseconds resolution for parallel beam

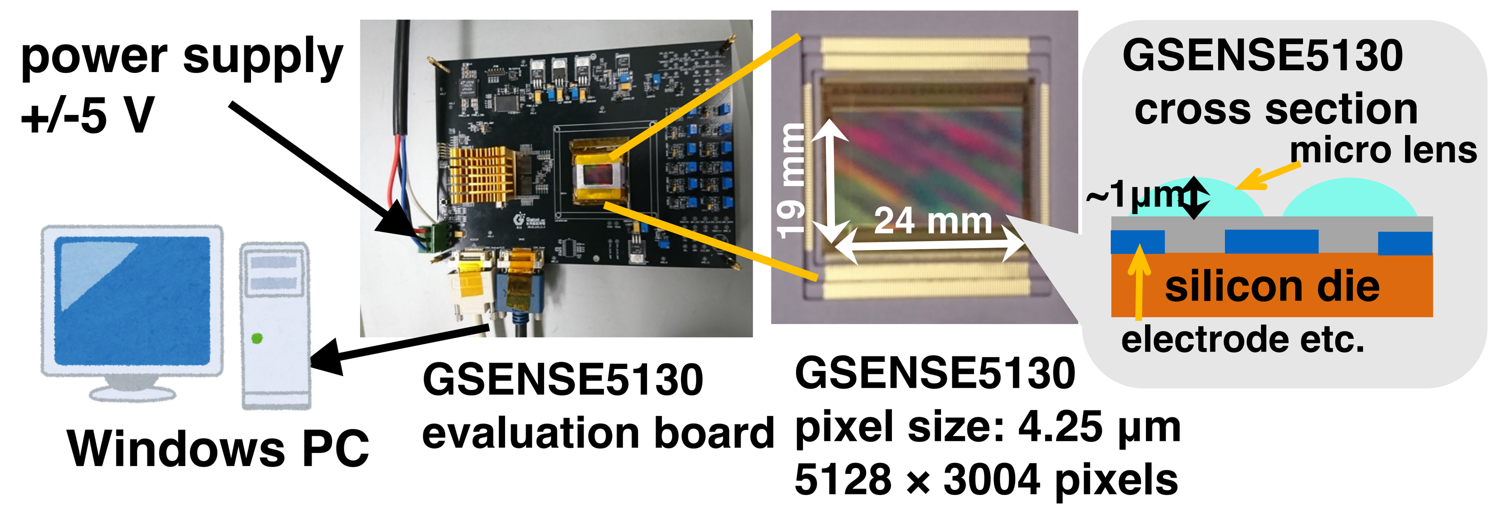
In this experiment, magnification of factor 4.4 helps us to detect the X-ray interference fringe. X-rays from celestial objects is parallel, and no magnification is expected. We thus need finer pixel detector of whch pixel size is similar or smaller than the grating pitch.

Reference

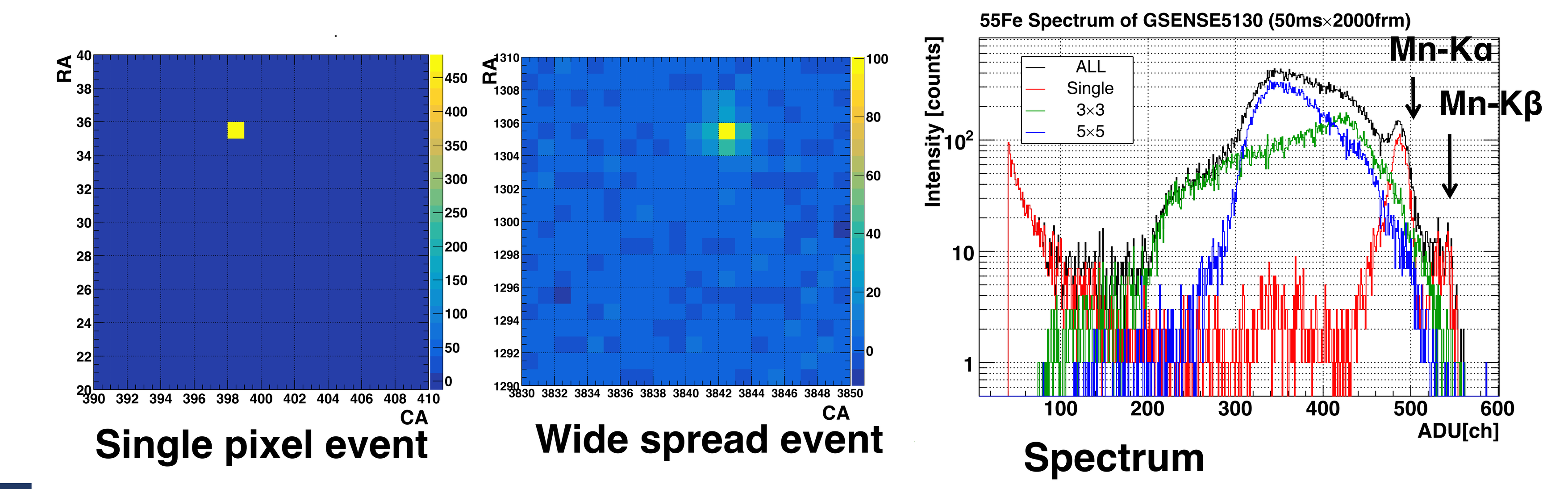
[1]Hayashida et al., 2016, SPIE proc., 9905, 99057
[2]Hayashida et al. P62 this conference

X-ray irradiation to CMOS Sensor GSENSE5130

We have introduced a CMOS sensor developed by Gpixel inc. with a small pixel size of 4.25 μm, GSENSE5130. GSENSE5130 is a front illuminated CMOS for visible light application and has micro lenses on chip. Digitized high gain and low gain data are output simultaneously from the chip. Two shutter modes, rolling and global are selectable, but we drive it with the rolling shutter mode.

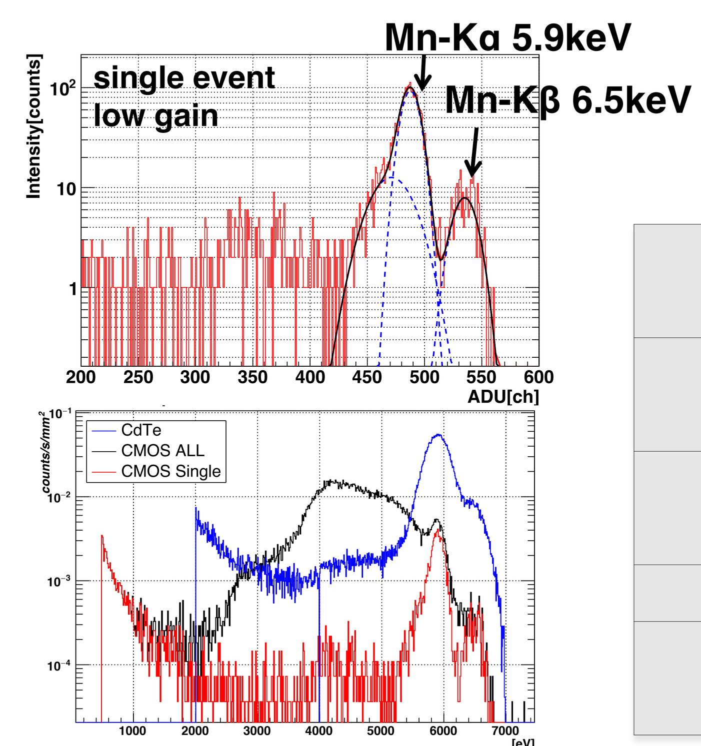


We first irradiated the sensor with 5.9 keV and 6.5 keV X-rays from an Fe-55 source and found that the sensor detect X-ray photons at room temperaure, open air.



Preliminary Evaluation of GSENSE5130

The energy resolution of GSENSE5130 at room temperature was evaluated with single pixel event spectrum for the Fe-55 source. The quantum efficiency (QE) of the device was measured by irradiating the Fe-55 source to a CdTe detector.

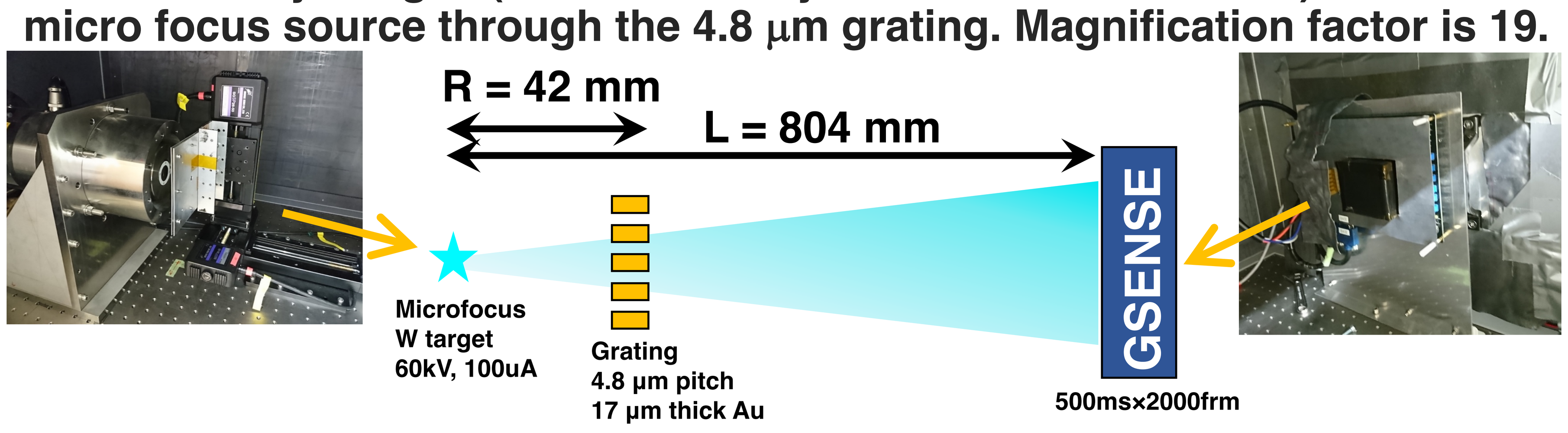


Assuming GSENSE5130 has a 1 μm thick dead layer (micro lens), the depletion layer in which single pixel events are generated has a thickness of 1 μm. But the X-ray sensitive layer for all kinds of events is as thick as 26 μm .

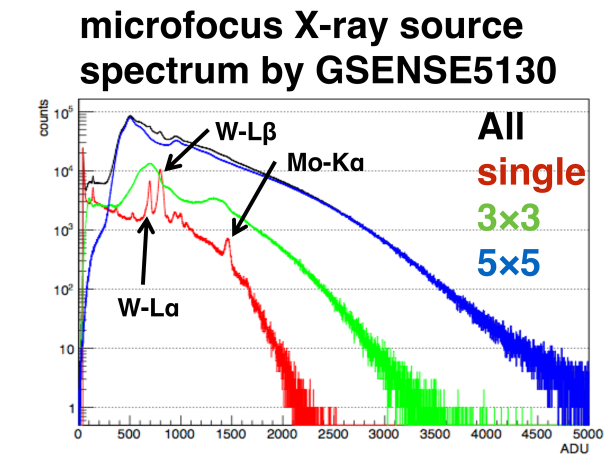
Gain	0.0083 ch/eV(low gain) 0.962 ch/eV(high gain)
Energy resolution (low gain)	FWHM@5.9keV = 238 eV FWHM@6.5keV = 278 eV
Readout noise	7.1e- (low gain) 1.5e- (high gain)
Dark current	3 e-/s/pixel@25deg
QE@5.9keV	3.0 % (single) 55.4 % (all event)

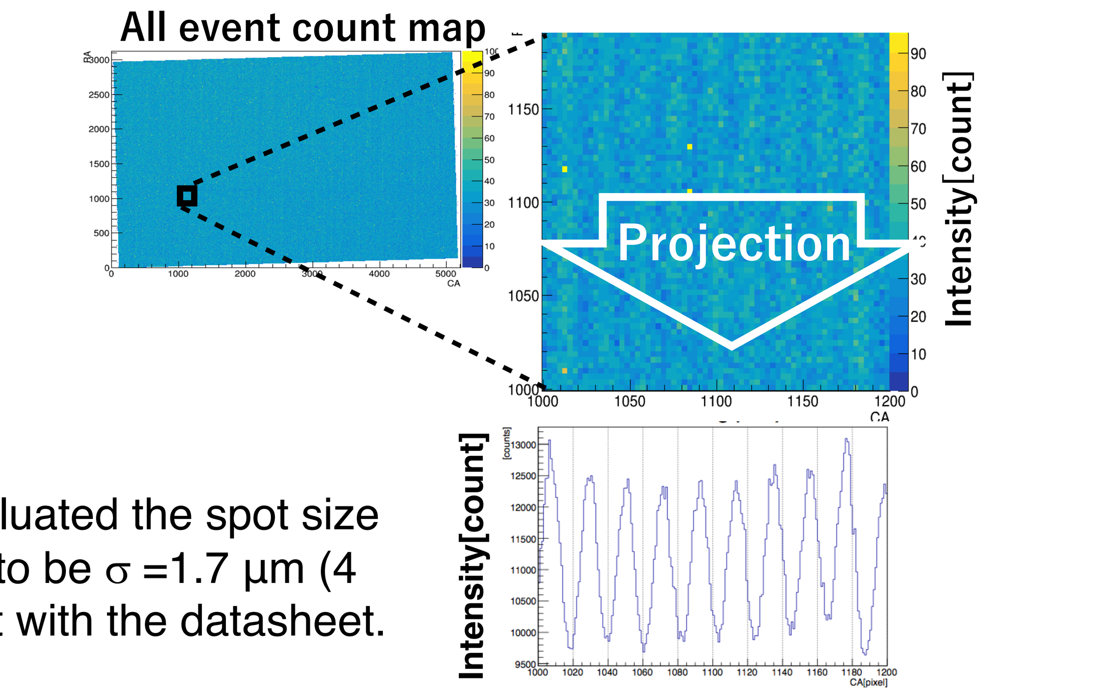
Imaging Experiment using GSENSE5130

We took X-ray images (not necessarily the Talbot interference) from the micro focus source through the 4.8 μm grating. Magnification factor is 19.



In this condition we could see 21 pixel period self image on GSENSE5130 without applying the charge sharing analysis.





With this measurement, we evaluated the spot size of the microfocus X-ray source to be σ =1.7 μm (4 μm FWHM), which is consistent with the datasheet.

Summary

We obtained the X-ray Talbot interference fringe with a 4.8 μm grating and 30 μm pixel XRPIX2b with a magnification factor of 4.4. We then introduced a CMOS sensor GSENSE5130 with a small pixel size of 4.25 μm. GSENSE5130 can detect X-rays at room temperature. The energy resolution is 240eV@5.9keV for single pixel events. We evaluated that GSENSE5130 has 1 μm thick depletion region and 26 μm thick sensitive region. We obtained X-ray images through the grating using GSENSE5130. We have performed parallel X-ray beam irradiation to GSENSE5130 plus grating at BL20B of SPring-8. X-ray polarimetry was also tested. The results will be shown later.