Performance of "μ-PIC" Gaseous Area Detector in Small Angle X-ray Scattering Experiments

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We report on the development of a two-dimensional photon-counting detector based on a Micro Pixel Gas Chamber (μ-PIC) for high-resolution Small Angle X-ray Scattering (SAXS) and for time resolved X-ray structure analysis. The μ-PIC is a micro-pattern gaseous detector fabricated with printed circuit board technology. In this article, the performance of the μ-PIC in SAXS experiments at SPring-8 is described. We obtained a dynamic range of over 10^5 for X-ray diffraction by PSLatex. The maximum counting rate of up to 5 MHz was observed with good linearity and without saturation. For a diffraction pattern of collagen, weak peaks in high angle region were observed in one accumulation of photons.

Road to a New Method for Structural Analysis

Our Goal

✓High Speed Analysis

biological macromolecules (protein), medicine, industrial materials

→ measurements in a couple of minutes

✓High precision

Detectors currently in use : dynamic range of $10^{4\text{-}5}$ (integration-type detectors; CCD and Imaging Plate)

Goal : dynamic range of $10^{7\text{-}8}$

→High Precision Measurements

✓Time resolved

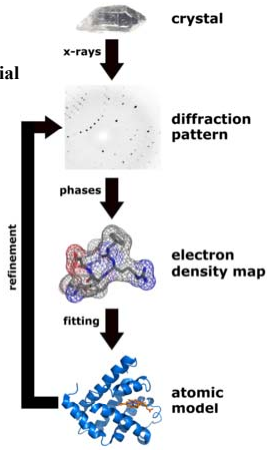
active dynamics

photon-induced phase transition

continuum transition (sec~ sub-msec)

Repeating measurements improves a time resolution.

→Need for a photon counting area detector with a high position resolution (difficult for integration-type detectors to realize a wide dynamic range and time resolved experiments)



Requirements for a photon counting area detector

1. Position resolution better than 100 μm
2. Counting rates > 10^7mm^{-2}, >1000× MWPC (irradiated locally)
3. Large size of active area > 15×15 cm^2
4. No dead region (ex. junctions)
5. Efficiency difference < 1 %
6. Image distortion < 1 %
7. Operation at room temperature, low power consumption
8. Easy maintenance
9. Low costs

A photon counting area detector based on a Micro Pixel Chamber (μ-PIC) has realized 4, 6, 7, 8, and 9.

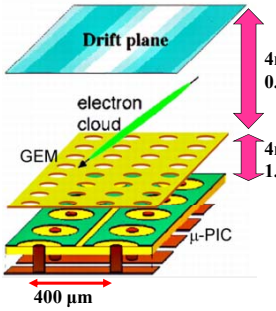
1, 2, and 5 are in progress.

3. A n active area of a μ-PIC currently in use is 10×10cm^2

A μ-PIC with an active area of 30 ×30 cm^2 has proved stable runs.

→ Verification experiments at a synchrotron radiation facility are being planned.

What is a Micro Pixel Chamber (μ-PIC)?



X-ray imaging detector μ-PIC

Electrode pitch : 400 μm

Max gas gain : 15,000

Stable gas gain : 6,000

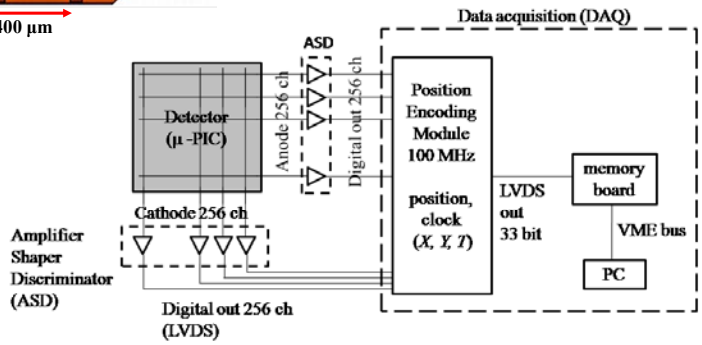
Position resolution : 120 μm

Preamplifier : Gas Electron Multiplier (GEM) [1] operated at a gas gain of ~10

Operated at a total gas gain of over 10, 000 (μ-PIC 4,000, GEM 3)

Contained in a sealed vessel

Gas : Xe 70 % C_2H_6 30 %, 1 atm

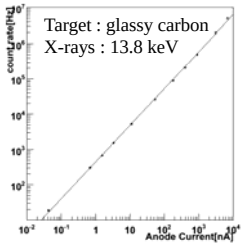


✓The output charges of the 256+256 channels are parallel pre-amplified, shaped, and discriminated by the ASD chips.

✓All discriminated digital signals are sent to the position encoding module based on FPGAs with an internal clock of 100 MHz, so that the anode and cathode coincident position = (*X*, *Y*) and the timing, *t*, are recorded into the memory module.

Performance studies of a μ-PIC irradiated with intense X-rays at Spring-8

Linearity in a data acquisition rate



The DAR and the leakage current show a good linear correlation from 20 cps to 5 Mcps (over 10^5).

Stable operation at 5 MHz

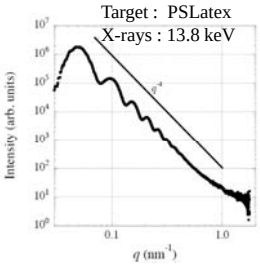
Good linearity in low counting rate environments

Dynamic Range

Dynamic range of over 10^5 was achieved.

Our goal : $10^{7\text{-}8}$

→further improvements efficiency, uniformity



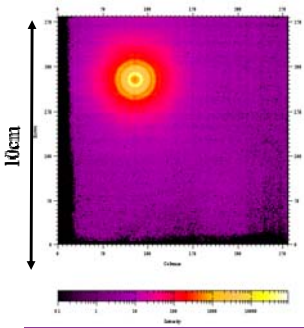


Image distortion

Target : SiO2 (110 nm, 5mg/ml)

X-rays : 13.8 keV

Raw data

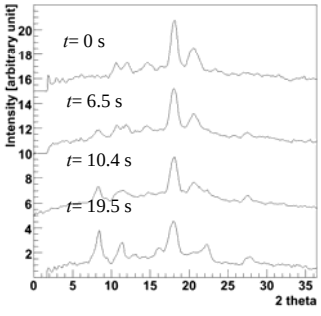
✓No efficiency calibration

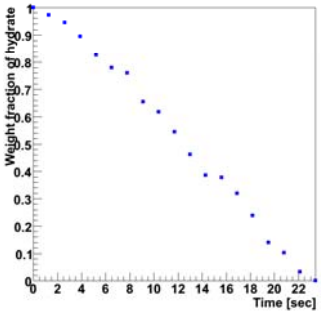
✓No image distortion

✓Proved uniformity

Time-resolved X-ray diffraction

Changes of a diffraction pattern in 20 sec





Dehydration reaction of a pyromellitic acid hydrate occurs when heat is applying. A weight fraction of the dehydrate, *x*, was observed for 20 s using a μ-PIC. The intensity $I(2\theta, t)$ is expressed as $I = xI_d(2\theta) + (1\text{-}x)I_h(2\theta)$, where $I_d(2\theta)$, $I_h(2\theta)$ is the intensity of the dehydrate, the hydrate, respectively, including a background.

Summary and Future Works

	Current Status	Goal
Pixel pitch	400 μm	200 μm
Position resolution	120 μm	60 μm
Number of channels	256 ×256	1500 ×1500
Active area	10 cm×10 cm	30 cm×30 cm
Gain	5×10^3 - 10^4	> 10^4
Gain variation	3.7 %	1 %
Global counting rates	< 5MHz	10MHz
Dynamic Range	<10^6	10$^{7\text{-}8}$
Uniformity of efficiency	~several %	< 1%
Image distortion	< 1%	<1%

[1] F. Sauli Nucl. Instr. and Meth. A 386 (1997) 531-534

URL http://www-cr.scphys.kyoto-u.ac.jp/index-e.html

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