EVALUATION OF IMAGE ACQUISITION USING SYNCHROTRON RADIATION IN CMOS SENSOR

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Abstract

In this paper, the purpose is to develop imaging technique of synchrotron radiation using CMOS image sensor. The detector using hybrid method to be research in this lab was used, in order to increase image signal. We made experiments with 1B2 Whitebeam/microprobe beamline in PAL (Pohang Accelerator Laboratory). Phosphor materials such as ZnS:(Ag,Li), ZnS:(Cu,Al), Y$_2$O$_3$:Eu were produced by spin coating on glass. Synchrotron radiation images were acquired and evaluated from monochromatic light from monochromator in PAL 1B2line. From obtained object and phantom, MTF was 0.15 in ZnS:(Ag,Li) phosphor, and 0.178 in ZnS :(Cu,Al) at 15 lp/mm. MTFs were unsystematic because thickness of phosphor and uniformity of surface were not optimized. It's expected to improve MTF and the quality of images as uniformity's optimized.

Key Words
Hybrid, CMOS image Sensor, monochromator, synchrotron radiation, phosphor

1. Introduction

In this study, we developed image detector for synchrotron radiation using CMOS image sensor. This detector has mixed structure that is composed of CMOS image sensor and scintillator. As developed image sensor manufacture technology using CMOS technology, the studies are advanced actively using CMOS image sensor, and it also surpasses CCD in pixel resolution.[5] The CMOS has a strong point that possibility of high frame embodiment for real-time images.[4] Around the world, the studies about image acquisition with synchrotron radiation were attempted by Ulrich Bonse and Michael Hart in Cornell University, 1965, [1] and now, In-vitro study such as Structural Biology, X-ray Microscopy and Radiation Cell Biology, in-vivo study of human body such as Coronary Arteries, Lungs, Breast Tumor(in-vitro tissue), and in-vivo study of animal such as Head and Neck, Brain Tumor are progressed. [2] X-ray imaging method with high energy, such as contact radiography, projection microscopy and X-ray tomography, has been used to reveal the inside structure of the object with non destructive at material science, biology, medical field. But contrast-images by absorption difference are mainly used in this method and the resolution is approximately 10 ~ 100 µm according to application field. Therefore, the resolution must be blow µm to reveal more detailed structures or moving properties. According to this necessary, the phase contrast image method is developed. Generally on inside structure test of organism system or low electric density materials, soft x-ray is better than hard x-ray. Because of thicker sample is tested with lower absorbed dose. In x-ray the refraction n is given,

$$n = 1 - \delta + i\beta$$

δ is refraction rate and β is absorption rate. Actually, β is almost 1 at x-ray of high energy and absorbed contrast doesn’t happened almost because according to atomic weight it changes a little.[6] Hence it can be measured with high resolution by detecting phase of wave from reduction of refraction rate δ.[7] The phase of the light will not be able to record directly in archival medium. Than after Gabor, many methods are developed and used. The soft x-ray uses a holography or zone plate while the hard x-ray uses two-beam interferometry and analyzer crystal. Recently it measured phase contrast image with in-line holography using coherent property of x-ray with high energy injected from the 3rd generation synchrotron radiation accelerator.

In this study, we experimented on image acquisition test from 1B2 White-beam/Microprobe beam-line of PAL(Pohang Accelerator Laboratory) using scintillator and CMOS image sensor. The synchrotron x-ray is converted into mono-beam by monochromator and injected sample. The x-ray image information of sample is converted into visible light by scintillator, and than acquired with CMOS. It obtained high-resolution phantom images and anchovy’s images with this method. The CMOS image are acquired like this, MTF(Modulation Transfer Function) is obtained, and the image quality is evaluated by fixed quantity.

2. Experimental

Critical 2.8KeV at 2GeV operation(5.5KeV at 2.5GeV) was used as a source of light, and the Source size is δx=160 µm ,δy=60 µm in POHANG Acceleration Laboratory. In this research, Si 4-crystal channel cut
A monochromator was installed and mono-beam was used. Mono-beam energy, which is made by monochromator in 1B2, is 8 KeV and wavelength is about 1.6. The distance from the beam port to the experimental equipment is about 25 m, and it's 5 cm from the sample to the image acquisition device. It's even better than x-ray, which is used in medicine, the images by phase contrast, not absorption contrast. Transmitted beam to the body have different refractive index, due to difference of refractive index there would be interference pattern. So dark colors are detected in boundary lines of bodies by interference patterns. Therefore, materials of low density which is located behind materials of high density can be detected. In this research, inside of the sample was imaged by using 8 KeV mono-beam. A image acquisition system of synchrotron x-ray consists of Al attenuator, X, Y, Z, linear stage control unit, Phosphor (ZnS:Ag Li(blue), ZnS:Cu Al(green), Y2O2S:Eu(red)), CMOS sensor, USB cable, image acquisition device(ppcap_pvoc430k_i2c). Scintillator, which is the type of powder was spin-coated on film. Figure 1 shows the system structure. In this research, CMOS image sensor has 640×480 pixel arrays, 5.2 μm×5.2 μm pixel size, and 30 frames/sec. Dose of synchrotron radiation was measured with the ion chamber(adves Corp). Incident x-ray can't be detected by visible light detectors because x-ray is not in visible light region. So x-ray should be converted to 475nm visible light using scintillator. CMOS sensor can detect converted visible lights. Image informations, which were detected by CMOS sensor, are transmitted to the computer through USB cable, and saved by using the image processing program(amcap_pvoc430k).

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MTF(f) = \frac{M_{out}(f)}{M_{in}(f)}
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10 μm, 15 μm, 20 μm, 25 μm, 30 μm scintillators to absorb red, blue, green were manufactured by spin-coating, and optimized images were acquired by CMOS sensor. Figure 2 shows CMOS image sensor and a block diagram. And figure 6 shows acquired phantom's image. Then MTF(Modulation Transfer Function) was calculated to evaluate the efficiency of detectors quantitatively.

### 2.1 Graphs, Tables, and Photographs

- **Figure 1.** The structure of the system
- **Figure 2.** A block diagram of CMOS sensor
- **Figure 3.** SEM image of phosphor
- **Figure 4.** Fish sample
3. Conclusion

Scintillator, ZnS:(Ag,Li), ZnS: (Cu,Al) converted x-ray to visible light, and the images of fish were acquired by CMOS sensor. Figure 5 is the image of fish which was acquired using scintillator 10 μm.

Scintillator, which is thicker than 10 μm, may make blurring of images by increasing light amount.[3] It's verified that the thicker scintillator Decrease MTF due to blurring. Figure 7, 8, 9 shows MTF to measure using 30 μm, 20 μm, 20 μm scintillator (ZnS:(Ag,Li),ZnS:(Cu,Al)). It's unable to acquire images using scintillator Y2O3:S:Eu(red) because there are too much blurring for mono-beam. 10 μm scintillator has best MTF in result to acquire phantom's images by scintillator thickness. Figure 3 shows SEM of 10 μm scintillator. In phantom image, MTF of 15lp is 45% in 10 μm scintillator ZnS:(Cu,Al). In this experiment, images were acquired using scintillator which has high MTF.

It's estimated that MTF is irregular because the thickness of scintillator and the uniformity of surface were not optimized. It's expected that MTF and image quality will be improved if surface of phosphor can be uniform. In this experiment, scintillator of 10 μm thickness has high MTF, but MTF in image qualities was irregular because uniformity of surface was not optimized. It's expected to acquire detailed images clinically as well as to improve qualities of images.

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References

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