Detectors

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Introduction

In 1990, the SPring-8 Project Team initiated a feasibility study on various types of X-ray detectors in order to evaluate their capabilities attainable when applied to the third generation synchrotron radiation experiments. Having completed the study, the project team decided to conduct five independent R&D programs on the following detectors in 1992 [1, 2]:

- 1D position-sensitive CdTe detector,
- Imaging plate detector,
- X-ray TV detector,
- Microstrip gas chamber, and
- Proportional scintillation X-ray imaging chamber.

During the course of directing these programs,the project team organized an international workshop thoroughly dedicated to "area detectors" in 1993, providing the researches involved in these R&D programs with an opportunity to present their attainments [3]. In addition, the project team dispatched the researchers to major synchrotron radiation facilities world-wide, respecting the importance of international communication in developing advanced X-ray detectors [4, 5].

CdTe Detector Program

The R&D group for CdTe detectors has been directed by Professor N.Sakai of Himeji Institute of Technology in collaboration with Shimadzu Co.. The detector has been considered as the most promising device for high energy Compton scattering experiments, because of its high detection efficiency to hard X-ray photons and of its cryogenic-free property. The group has already developed a full-scale model, of a size 64 mm × 128 mm with 512 independent channels. Each channel is composed of eight linearly arranged CdTe unit sensors (0.25 mm in width, 8 mm in length, and 0.8 mm in thickness). The unit sensor is associated with its own electronics consisting of a preamplifier, a lower-level discriminator, and a counter. By using the full-scale model, the group has measured Compton profiles of aluminum samples under irradiation of hard X-ray at PF/KEK. The latest experimental data indicated that the Peltie device recently introduced to the system succeeded in regulating the thermal instability of the electronics, thus suppressing the sensitivity fluctuation previously appearing over the readout channels down to very close to the statistical limit [6].

Imaging Plate Detector Program

The R&D group for imaging plate detectors has been conducted by Dr. N. Kamiya of the SPring-8 Project Team in collaboration with Rigaku Co., Tokyo Instruments Co., and Kino-Meresgrio Co.. In order to effectively acquire a vast amount of information recorded on each imaging plate in the field of protein crystallography, it has been their concept to construct such a system that is fully on-line, being capable of reading out an extensive imaging plate of 400 mm × 600 mm within a minute. The group has intensively examined the scanning mechanism associated with line-shaped laser light in order to shorten the readout time. In this readout scheme, the photostimulated luminescence induced by the laser light will be focused onto a CCD through an optical lens system of large numerical aperture and will be read out one-dimensionally with a readout cycle of 430 kHz. The group has also carried out an experimental study on a new type of imaging plate called Blue IP (Fuji film BAS-UR), demonstrating that the spatial resolution and the dynamic range can be as high as 53 μm × 78 μm and wider than 4 orders of magnitude, respectively. The systematic evaluation on this newly designed imaging plate detector is currently in progress [7, 8].

X-ray TV Detector Program

The R&D group for X-ray TV detectors has been conducted by Professor Y. Amemiya of Photon Factory at KEK in collaboration with Hamamatsu Photonics Co.. They have regarded X-ray image intensifiers as one of the most promising TV-based detectors for time-resolved 2D imaging needed in small angle scattering experiments. The group has been successfully enlarging the Be-windows of the devices from 150 mmϕ up to 220 mmϕ on the basis of a technology developed for medical X-ray image intensifiers. In order to suppress the image distortion caused by an environmental magnetic field, they have elaborated an on-site image distortion monitoring system. Confirming that the X-ray image intensifiers have dynamic ranges wider than 5 orders of magnitude and point spread functions with a FWHM less than 300 μm, the group has succeeded in observing time-resolved diffraction patterns from, for example, frog skeletal muscle during contraction under stretch at Photon Factory of KEK. As far as the R&D activities are concerned, the program have been accomplished by the time of writing this report [9].

Microstrip Gas Chamber Program

The R&D group for microstrip gas chambers has been directed by Professor T. Tanimori of Tokyo Institute of Technology in collaboration with Toshiba Co.. Because of its excellent time resolution as short as 10 nsec, the chamber has been regarded as a highly promising instrument in protein crystallography to be carried out at the third generation synchrotron radiation facilities. The group has already developed a two-dimensional prototype chamber having an effective area of 50 mm × 50 mm with a very thin substrate made of polyimide by employing multi-chip module technology (Fig.1). The microstrip structure on the chip was carefully designed by using a computer code of electric field calculations in order to strictly prevent the insulator used in the chamber from accumulating positive ions, which could induce a long-term gain instability and eventually result in local discharge. The chip fabricated so far has 250 anode strips and the equal numbers of backplane strips, orthogonal oriented to each other, having an expected spatial resolution of 60 μm. The chip is mounted on a ceramic package with 600 connected pins, realizing easy and high-density connections. The group has also developed a diagnostic system for multichannel electronics to effectively perform the checking process of the front-end electronics and the data acquisition system associated witha large number of channels. They have succeeded in operating the microstrip chamber stably, reproducing the X-ray image of a test pattern under the irradiation of X-rays emitted from a radioisotope [10].

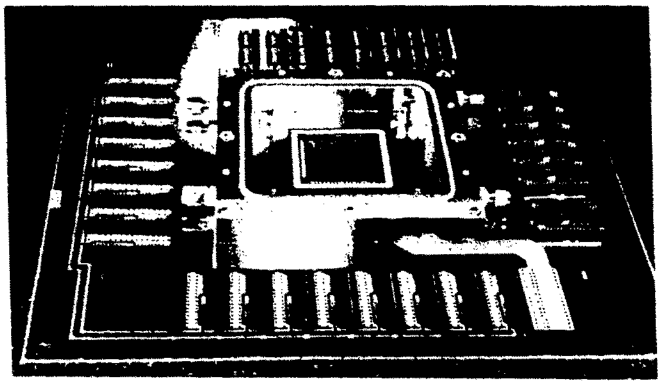

Fig.1 Microstrip gas detector in its gas vessel together with the associated front-end electronics.

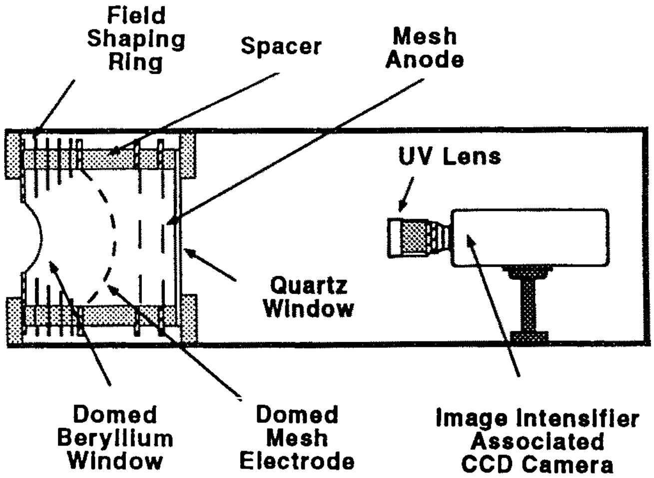

Fig.2 Schematics of proportional scintillation X-ray imaging chamber.

Proportional Scintillation X-ray Imaging Chamber Program

The R&D group for proportional scintillation X-ray imaging chambers has been directed by one of the authors (M.Suzuki). The instrument consists of a gas chamber and an imageintensifier-associated CCD camera (Fig. 2). The gas chamber is composed of a spherical drift chamber and a parallel plate avalanche chamber. The spherical drift chamber functions as a conversion volume of incoming X-rays into secondary electrons, suppressing the parallax error as well. The avalanche chamber generates the proportional scintillation with a luminous pattern reproducing the spatial distribution of the secondary electrons, which is the projection image of the incoming X-rays. The optical pattern is viewed with the CCD camera, which provides video signals of the X-ray images in real time. The most outstanding feature of this instrument is its high space-charge resistivity due to the relatively low applied electric field employed, under which practically no electron multiplication could proceed. The group has examined the basic performance of the instrument by observing the diffraction patterns of several well-known samples at Photon Factory of KEK. They have also confirmed that the instrument can successfully monitor the monochromatized direct beam without any instabilities for longer than one hour, providing real-time 2D beam profile images continuously [11].

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