SPring-8 Detector Projects

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1. Introduction

Since the inauguration of the SPring-8 facility in October of 1997, the Station Equipment Group belonging to the Experimental Facilities Division of the Japan Synchrotron Radiation Research Institute (JASRI) has officially taken over X-ray detector projects formerly initialized and carried our by the SPring-8 Project Team.

While the Project Team was responsible for detector programs at SPring-8, they focused their efforts on such X-ray detectors as microstrip gaseous chambers (hereafter referred to as MSGCs) or multiple CCD X-ray detectors (hereafter referred to as MCCDXs), which employ leading-edge technologies.

Due to the interdisciplinary nature of synchrotron radiation science, however, it was soon anticipated that a whole range of X-ray detectors would become needed at the facility upon its inauguration. The group has therefore began committing itself toward providing technical support for X-ray detectors like X-ray image-intensifier systems coupled with cooled CCD cameras, which are considered to be technologically well-matured and reliable enough for general use. In addition, the group has initiated basic research on such X-ray detectors as ionization chambers, whose operational principles have become subject to serious reexaminations under high-flux X-ray beam conditions.

2. The MSGC Project

The MSGC project is one of the ongoing R&D programs of SPring-8 formerly undertaken by the Project Team and presently by the Station Equipment Group in collaboration with Tanimori's group of Tokyo Institute of Technology. The goal assigned for the project is to achieve a high-flux X-ray imaging detector at RIKEN Beamline I (BL45XU) [1-4].

As was reported last year, the groups have fabricated a first prototype, which possesses an effective detection area of 50 mm $\times$ 50 mm having anodes and cathodes both printed at intervals of 200 μm. They have succeeded in demonstrating that the position resolution can be better than 100 μm with the prototype.

Based on this result, they subsequently constructed an advanced model of MSGC in 1997, whose detection area extends up to 100 mm $\times$ 100 mm. In parallel, the group fabricated a faster data acquisition system thoroughly dedicated to time-resolved X-ray imaging [3,4]. Since this system is operated with a clock cycle of 10 MHz, the counting rate can reach 3.2 Mcps, enabling the MSGC to resolve X-ray images on the time scale of submilliseconds. With an observed transmission image of a printed circuit board, it could be confirmed that the image distortion occurring in the new model is highly suppressed to below the 0.5% level.

Initial on-beamline tests of the new system were carried out in December 1997 at the SAXS experimental station of RIKEN beamline I, with samples of the collagen of chicken tendon, frog skeletal muscle, and lysozyme solution.

3. The MCCDX Project

The MCCDX project is another ongoing program, with which the Station Equipment Group is proceeding in collaboration with the SR Structural Biology Research Group of RIKEN as well as with EEV in the UK.

Having successfully completed the construction of a 4$\times$4 array CCD X-ray detector system and having examined it with a conventional X-ray generator system in 1996 [5,6], the group proceeded on to the systematic evaluation of the acquired X-ray image data in terms of image distortions, the spatial resolution, the non-uniformity of the X-ray sensitivity, and the dynamic range. In reference to the beam spots precisely located on the detection area, it was found that the image distortions observed were of the order of 0.1 mm and 2 mm at the centers and at the edges, in the CCD X-ray detector modules of the system, respectively.

The horizontal and vertical spreads of the X-ray beam spots were estimated to be 164 $\pm$13 μm (FWHM) and 188 $\pm$ 25 μm (FWHM), respectively, and were very close to the extension of the incident X-ray beam itself, strongly suggesting that the spatial resolution of the MCCDX is much better than these values. The non-uniformity of the X-ray sensitivity that the MCCDX system inherently possesses was also investigated by irradiating the system with quasi-flat field X-rays produced by a conventional X-ray generator system. The sensitivity was found to decrease down to 80% from the center to the edge of each CCD

X-ray detector module. From a noise analysis, it was confirmed that the dynamic range fairly exceeds 12 bits in all of the X-ray detector modules.

The MCCDX was subjected to its first on-beamline test on December 4, 1997 at RIKEN beamline I, and acquired X-ray diffraction images from an enzyme crystal of lysozyme, well demonstrating that the MCCDX has attained functional specifications as designed.

3. CCD-Based Detectors

The Station Equipment Group made two CCD-based detector systems available for general use by users of SPring-8 during 1997.

The first one is an X-ray image-intensifier coupled with a cooled CCD camera. The X-ray image-intensifier is a Hamamatsu Photonics V5445P which has a 15-cm diameter beryllium window. The phosphor in the input screen is CsI and that in the output screen is P-20. Three types of cooled CCD cameras can be combined with the image-intensifier through a tandem optical lens system: C4880-17 with 1000×1018 12 μm pixels (for high resolution), C4880-72F with 512×512 24 μm pixels (for a wide dynamic range with a well-depth of 300,000 electrons), and C4880-82 with 656×494 9.9 μm pixels (for fast readout up to 28 frames/sec). All of the CCDs are vacuum-sealed and the Peltier device is cooled by air. Therefore, neither a vacuum pump nor a water cooling pump is required for operation, making the system transportable and easy to use.

The second one is a CCD-based beam monitor. This new detector was designed and manufactured to directly visualize an X-ray beam. It is called a "Beam Monitor" and is described in a separate report in this issue [7].

4. Ionization Chambers

The Station Equipment Group has long been concerned with the behavior of ionization chambers especially when they are irradiated with a high-flux X-ray beam. It has been reported that the recombination process between the positive and negative charges generated in an ionization chamber can be significant when the ionization current exceeds 1 μA. In such cases, the ionization chamber can cease to function as a conventional beam intensity monitor in the high-flux X-ray beam experiments [8].

Having confirmed its ordinary behavior with an X-ray beam generated at a bending magnet of BL01, the group carefully examined the response of an ionization chamber to a high-flux X-ray beam generated with an undulator of BL47. The ionization current was measured as a function of the applied electric field in various gases in order to examine systematically the saturation characteristics .

As anticipated, it was clearly observed that the current saturation can not be accomplished in heavier gases, *e.g.*, krypton or xenon, even at the maximum rating of the applied electric field. This can be attributed to the shorter absorption length and the shorter electron range in these gases, both of which contribute to increasing the densities of the positive and negative charges, facilitating the recombination process. It is, therefore, the current conclusion of the group to exploit the ionization chamber operated in lighter gases.

5. Concluding Remarks

Having succeeded the detector group of the Project Team, the Station Equipment Group is proceeding with two strategically important projects, *i.e.*, the MSGC project and the MCCDX project, to be used in real applications. In parallel, they started committing themselves to the support of several conventional X-ray detectors as well as to the characterization of these detectors under high-flux X-ray beam conditions. The group will take research activities in these directions in the following year as well facilitate various types of experiments proposed at SPring-8.

References

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