# Performance of a Proportional Scintillation X-ray Imaging Chamber

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## Introduction

X-ray scattering experiments with ex tremely brilliant x-ray beams available at the third-generation synchrotron radiation facilities like SPring-8, APS, and ESRF promise to provide a wealth of information on the properties of materials. Two-dimensional position-sensitive x-ray detectors are expected to play an important role in this field of experiments. As represented by multiwire proportional counters (MWPC), gaseous detectors have widely been in use in synchrotron radiation science, because of their excellent S/N ratios, large dynamic ranges, and relatively fast operations. It is, however, questioned whether gaseous detectors based upon the electron multiplication process can successfully function when applied to the third-generation synchrotron radiation sources due to the space charge abundantly generated and multiplied in the detectors.

One of the approaches towards the space charge prob lem so far challenged is to make the ion collection time in a MWPC as short as possible by narrowing the gap between the cathodes [1]. As long as the ions are swept out before the next x-ray photon arrives, the MWPC will not seriously be subject to the space charge problem. Microstrip gas detectors being introduced to synchrotron radiation science can be regarded as an extreme case of this approach [2].

Another way of approaching towards the space charge problem is to operate a gaseous detector in the region of *proportional scintillation*. In this mode the photon amplification process can proceed but not the electron multiplication because of the much lower electric field applied than that in the proportional mode. Operation in the proportional scintillation mode, therefore, drastically reduces the space charge down to the primary ionization level. In this operational scheme, the position information on incoming x-ray photons can be optically read out from the detector with a highly sensitive video camera. Since 1993, we have been proceeding a R&D program, "*Proportional Scintillation x-ray Imaging Chamber Project,*" in order to realize this concept. Having constructed and operated a prototype, we intensively investigated its performance in various aspects as described below [3, 4].

## Experimental

As Fig.1 displays, the prototype consists of a spherical drift chamber (SDC), a parallel plate avalanche counter (PPAC), and an image-intensifier-associated CCD camera (ICCD). The SDC is bounded with a beryllium dome, a mesh dome and 4 field shaping rings. The beryllium dome has a thickness, an opening radius and a bending radius of 100 μm, 50 mm, and 80 mm, respectively. The mesh dome is located 6 cm apart from the beryllium dome, having an opening radius and bending radius of 8.5 cm and 14 cm, respectively. The mesh used is made of stainless steel with a wire diameter of 0.29 mm and a spacing of 5 mm. The field shaping rings are inserted in the drift volume with an interval of 1 cm in order to ensure the spherical structure of the electric potential surfaces. The electric field strength is set to be 100 volts/cm in the SDC. The PPAC is defined with a pair of mesh electrodes and an optical window. The meshes used for both electrodes are cross-wire type with 50 μm wire diameter and 500 μm spacing. The gap between the two meshes is set to be 7 mm. The optical window made of quartz glass is located 2 cm behind the second mesh. It has a diameter and a thickness of 16 cm and 6 mm, respectively. All the electrodes configuring both the SDC and the PPAC are assembled with precisely machined plastic spacers and silicon rubber O-rings, and tightened onto a duralumin flange with stainless steel bolts.

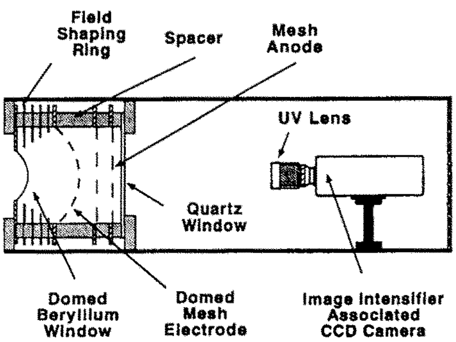


Fig.1 Schematics of proportional scintillation x-ray imaging chamber.

A gaseous mixture of xenon (97%) + triethylamine (TEA) (3%) is continuously supplied to the prototype with a flow rate of 100 cc/min. The purities of xenon gas and liquid TEA are better than 99.995% and 95%, respectively. The xenon gas first passes through a bubbler containing liquid TEA kept at 8 °C in a refrigerator. After catching the vapor of TEA, the xenon gas is filtered with a molecular sieve trap to eliminate residual water vapor and then supplied to the chamber.

The ICCD is located 60 cm apart from the optical window of the PPAC. The unit is composed of a UV objective, a UV sensitive image intensifier, and a CCD camera. It has a minimum photocathode brightness of $4 \times 10^{-7}$ lx with a spectral response from 180 to 850 nm, which effectively covers the emission spectrum of xenon + TEA proportional scintillation in near UV region. The CCD camera resolves the output images from the image intensifier with 768 × 493 pixels, which corresponds to a spatial resolution of 210 μm × 320 μm on the second mesh of the PPAC. The images stored in these pixels are read out every 1/30 sec in frame mode, and are converted into the NTSC standard video signals. The video images are monitored on a TV screen and are recorded with a video recorder. They are also digitized into 8 bits with a video frame grabber installed in a Macintosh IIci for further analysis and storage.

## Results and Discussion

Having installed the prototype on the BL-14C at the Photon Factory of KEK, we examined the x-ray imaging capability of the prototype by observing the diffraction patterns of the several well-known samples [5]. Since x-ray photons observed in video frames were superimposed each other because of the high counting rate, we operated the prototype with such a low photon gain that the local intensity of the proportional scintillation represented the two-dimensional x-ray intensity distribution (analogue mode). Figure 2 displays the observed diffraction pattern of β-cyclodextrn powder with integrating 255 video frames. We can see not only the ordinary circular diffraction pattern but also the several Laue spots due to the remaining crystal structure in the sample. The spatial resolution attained in this analogue mode was better than 1 mm (FWHM). After reducing the gains of the PPAC and the ICCD, we irradiated the prototype with the monochromatized direct beams (20keV,~$10^8$photons/mm$^2$ /sec) on the BL14-C in order to study its space-charge-resistivity. As shown in Fig.3, the prototype succeeded in stably visualizing the direct beam images without any instabilities for longer than 1 hour.

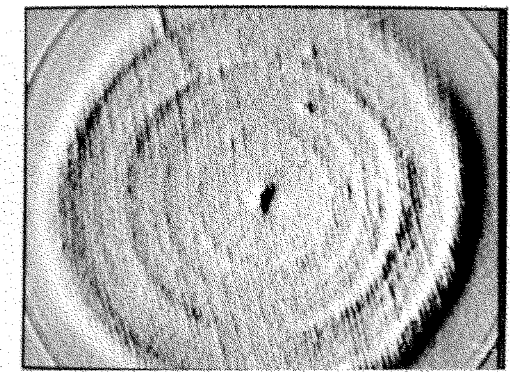

Fig.2 Observed Lau diffraction pattern β-cyclodextrn.

With increasing its sensitivity to the single x-ray photon counting region (digital mode), we also irradiated the prototype with x-rays emitted from an $^{55}Fe$ source. The single x-ray photons were successfully imaged with the prototype as bright spots of 1.4 mm in diameter as expected. From the two-dimensional distribution map of the single x-ray photons detected, we evaluated the absolute detection efficiency and the fluctuation in the light gain uniformity over the entrance window to be 2.4% and less than 7%, respectively, both being consistent with the expected values. The spatial resolutions attained in digital mode were found to be better than 170 μm. By taking x-ray images in the time scale of 1/10 sec, we also confirmed that the prototype is capable of performing time-resolved imaging experiments with a time resolution of 1/30 sec.

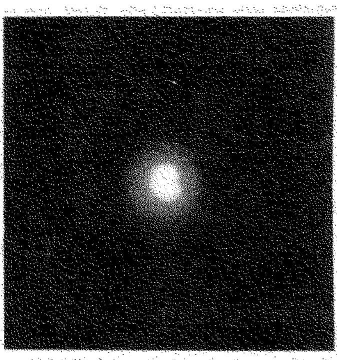

Fig.3 Observed monochromatized direct beam image.

## References


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