Quasi-monochromatic Parallel Radiography Achieved with a Polycapillary Plate

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ABSTRACT

Fundamental study on quasi-monochromatic parallel radiography using a polycapillary plate and a plane-focus x-ray tube is described. The x-ray generator consists of a negative high-voltage power supply, a filament (hot cathode) power supply, and an x-ray tube. The negative high-voltage is applied to the cathode electrode, and the transmission type target (anode) is connected to the ground potential. The maximum voltage and current of the power supply were −100 kV (peak value) and 3.0 mA, respectively. In this experiment, the tube voltage was regulated from 20 to 25 kV, and the tube current was regulated by the filament temperature and ranged from 1.0 to 3.0 mA. The exposure time is controlled in order to obtain optimum film density, and the focal spot diameter was about 10 mm. The polycapillary plate is J5022-21 made by Hamamatsu Photonics Inc., and the outside and effective diameters are 87 and 77 mm, respectively. The thickness and the hole diameter of the polycapillary are 1.0 mm and 25 μm, respectively. The x-rays from the tube are formed into parallel beam by the polycapillary, and the radiogram is taken using an industrial x-ray film of Fuji IX 100 without using a screen. In the measurement of image resolution, we employed three brass spacers of 2, 30, and 60 mm in height. By the test chart, the resolution fell according to increases in the spacer height without using a polycapillary. In contrast, the resolution slightly fell with corresponding increases in the height by the polycapillary. In angiography, fine blood vessels of about 100 μm are clearly visible.

Keywords: Monochromatic parallel radiography, polycapillary plate, plane-focus tube, transmission-type x-ray tube

1. INTRODUCTION

So far the synchrotron generates high-dose-rate monochromatic x-rays using silicon monochromators. These rays play important roles in parallel radiography,[1,2] and we tend to long for possible applications for a long time. However, it is difficult to obtain sufficient machine times for various researches and to apply monochromatic x-rays to various medical radiographies.

By forming the linear plasma x-ray source,[3-5] intense characteristic x-rays have been produced because the bremsstrahlung x-rays with photon energies of higher than K-absorption edge are absorbed by the weakly ionized plasma and are converted into fluorescent (characteristic) x-rays. So as to perform high-resolution radiography achieved

with quasi-monochromatic flash x-rays, the optimum x-ray optical system is desired, and parallel radiography utilizing a film-less computed radiography (CR) system has been performed using a polycapillary plate.[6]
Recently, several different x-ray lenses have been developed, and a polycapillary plate is useful to realize a low-priced x-ray system and to perform parallel radiography. Using a conventional x-ray generator having a tungsten target radiation tube, we have performed parallel radiography[7] and have obtained image resolutions of about 50 μm or less. However, because the tube has a small focal spot of about 1 × 1 mm, the irradiation field is very small. In order to increase the field using a polycapillary plate, the spot dimension should be increased as large as possible.
For this research, we have performed tentative study on quasi-monochromatic parallel radiography achieved with a polycapillary plate and a plane-focus x-ray tube in order to create a new x-ray generator instead of synchrotron.

2. SETUP

Figure 1 shows a method for performing parallel radiography using a polycapillary plate. The quasi-monochromatic x-rays from the plane-focus x-ray tube are formed into parallel beam by the polycapillary, and a radiogram is taken by using an x-ray film.
The x-ray tube employs a molybdenum target and a beryllium window (Fig. 2). The distance between the x-ray focus and film is 0.94 m, and the polycapillary plate is placed on the brass spacer, and the radiogram is roughly observed by a setup of screen and mirror.
The polycapillary plate is J5022-21 made by Hamamatsu Photonics Inc., and the outside and effective diameters are 87 and 77 mm, respectively. The thickness and the hole diameter of the polycapillary are 1.0 mm and 25 μm, respectively. Almost cone beam from a plane-focus tube are formed into parallel beam, and the radiogram is taken using an industrial x-ray film (Fuji IX 100) without a screen.
The circuit diagram of x-ray generator is illustrated in Fig. 3, and the generator consists of a negative high-voltage power supply, a filament power supply, and an x-ray tube. The negative high-voltage is applied to the cathode electrode, and the transmission type target (anode) is connected to the ground potential. The maximum voltage and current of the power supply are −100 kV (peak value) and 3.0 mA, respectively. In this experiment, the tube voltage was regulated from 20 to 25 kV, and the tube current was regulated by the filament temperature and ranged from 1.0 to 3.0 mA. The exposure time is controlled in order to obtain optimum film density, and the focal spot diameter was about 10 mm.

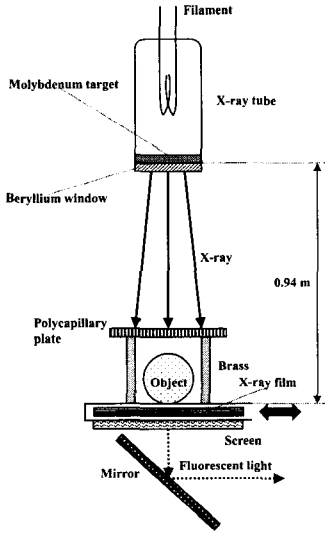


Fig. 1: Parallel beam radiography achieved with a plane-focus x-ray tube.

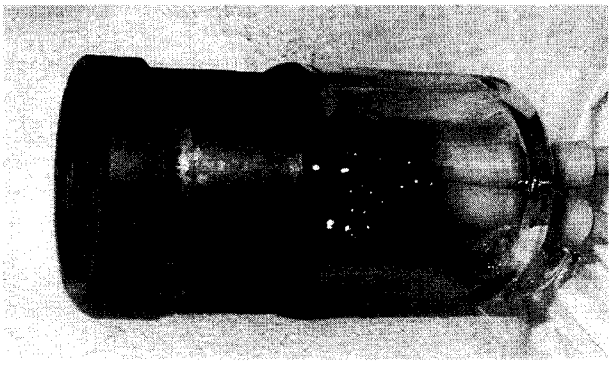


Fig. 2: Transmission type quasi-monochromatic x-ray tube.

3. X-RAY SPECTRA

In order to measure x-ray spectra, we employed a cadmium tellurium detector of CDTE2020X made by Hamamatsu Photonics Inc. (Fig. 4). Compared to a germanium detector, this detector has lower energy resolutions, and the characteristic x-ray intensity increased with corresponding increases in the tube voltage at a constant tube current of 1.0 mA. Next, the energy width decreased by the insertion of 30 μm molybdenum filter.

4. RADIOGRAPHY

The quasi-monochromatic radiography was performed with a charging voltage of 22.5 kV and a distance between the film and x-ray focus of 0.94 m. Figure 5 shows radiography for imaging a polycapillary plate, and the radiograms of the polycapillary are shown in Fig. 6. The center of black spot in the polycapillary radiogram is almost imaged by direct transmission beams through capillary holes. As shown in this figure, both the spot density and the dimension seldom varied according to increases in the brass-spacer height.

Fig. 7 shows two angiograms of a heart extracted from a rabbit using iodine-based micro spheres. When the polycapillary is employed with a spacer height of 22 mm, fine blood vessels of about 100 μm are clearly visible.

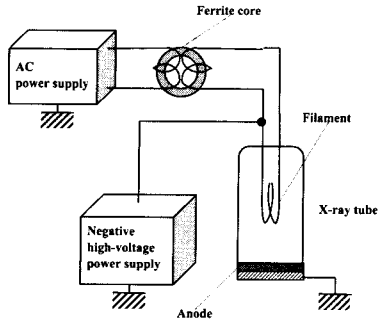


Fig. 3: Circuit diagram of x-ray generator.

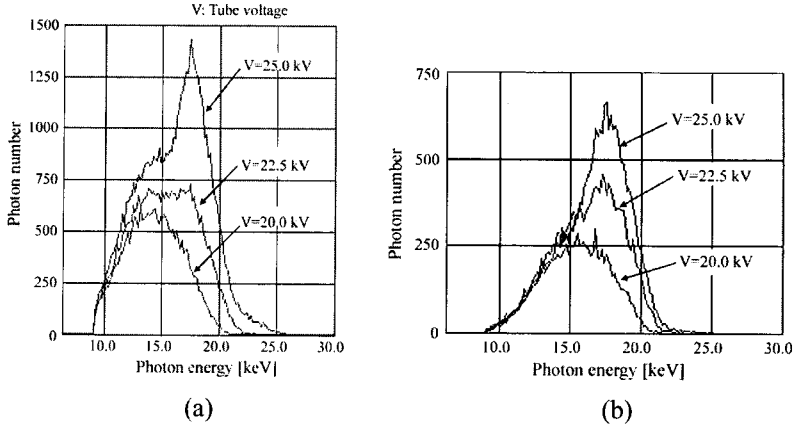


Fig. 4: Measured x-ray spectra according to changes in the tube voltage (a) without using a filter and (b) using a 30 μm molybdenum filter.

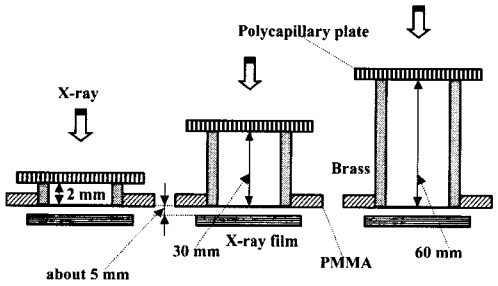


Fig. 5: Radiography for imaging a polycapillary plate according to changes in the spacer height.

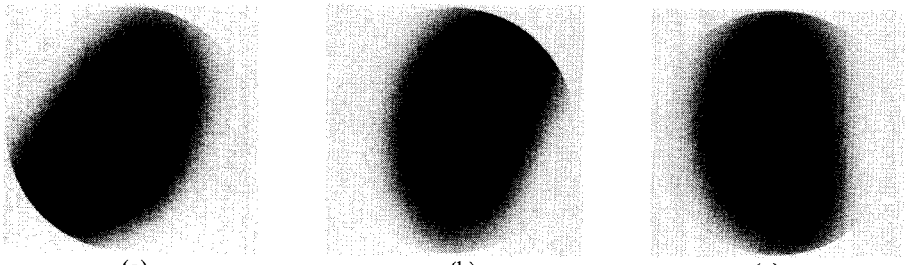
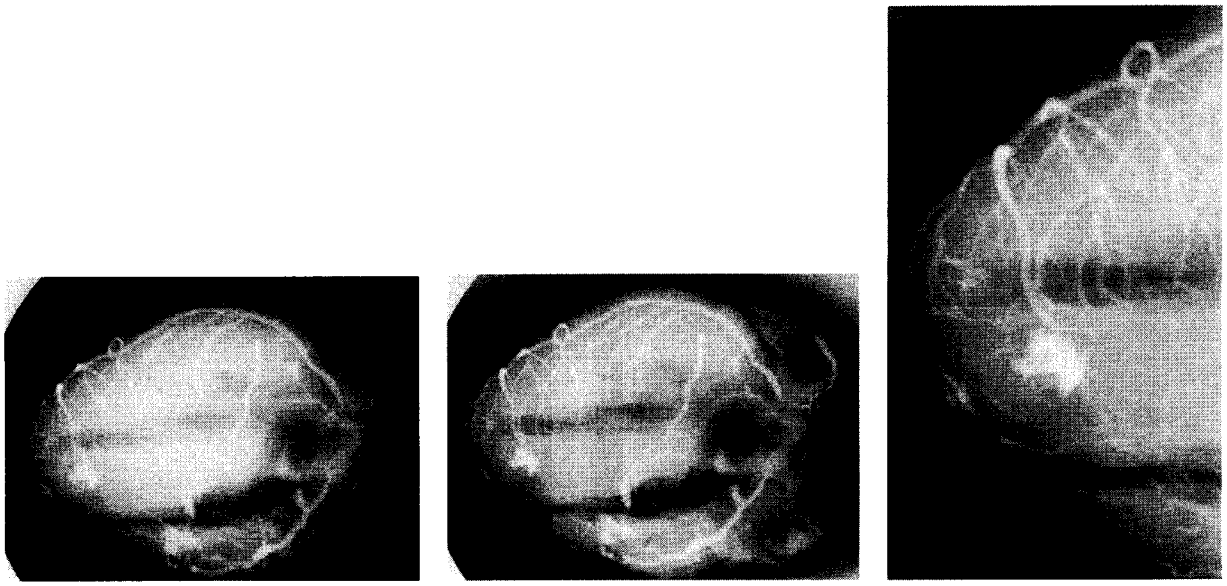


Fig. 6: Radiograms of a polycapillary plate with a spacer height of (a) 2 mm, (b) 30 mm, and (c) 60 mm.

5. DISCUSSION

Using this polycapillary, we have obtained higher image resolutions and contrasts, and the resolution improves with corresponding decreases in the capillary diameter. In the spectrum measurement, although molybdenum characteristic x-rays were observed with tube voltages of higher than 22.5 kV, we have to employ germanium detector to increase energy resolution.



(a) (b) (c)

Fig. 7: Angiograms of a heart extracted from a rabbit using iodine-based micro spheres with a charging voltage of 22.5 kV (a) without using a polycapillary, (b) using a polycapillary and a 22 mm spacer, and (c) using a polycapillary (enlarged radiogram).

For this research, we have performed parallel radiography achieved with a polycapillary plate in conjunction with a quasi-monochromatic x-ray tube. In the former experiment, we employed tungsten target with L-series characteristic x-rays of about 10 keV and obtained higher image resolutions. Therefore, we have to employ a thicker capillary so as to improve resolution by decreasing penetrating x-rays. Using this radiography, because it is possible to improve the image resolution and to employ quasi-monochromatic x-rays, this system can be applied to image a wide variety of objects in various fields including medical radiography.

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