

Image characteristics of the novel x-ray tube for the KSTAR x-ray image crystal spectrometer

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A novel x-ray tube, consists of an anode and a line filament as a cathode, has been developed [1-2]. Figure 1(a) shows the x-ray tube and a vacuum chamber used in the experiment measuring the energy spectrum of x-rays from the x-ray tube. Details on the x-ray tube were described in previous papers [1-2]. The 20° planned anodes were used in the x-ray tube for the higher intensity of x-rays and the anodes were made of Cu and Al (see Fig. 1(a)). The x-ray spectrum was measured with a Si (Li) detector (EG&E ORTEC, SLP-10180P). The channel-energy of the Si (Li) detector was calibrated by using Cu K α and Cu K β lines at 5.899 and 6.490 keV, respectively in the spectrum from the x-ray tube using a copper anode. Figure 1(b) shows typical energy spectra of x-ray from the x-ray tube using Cu and Al anodes.

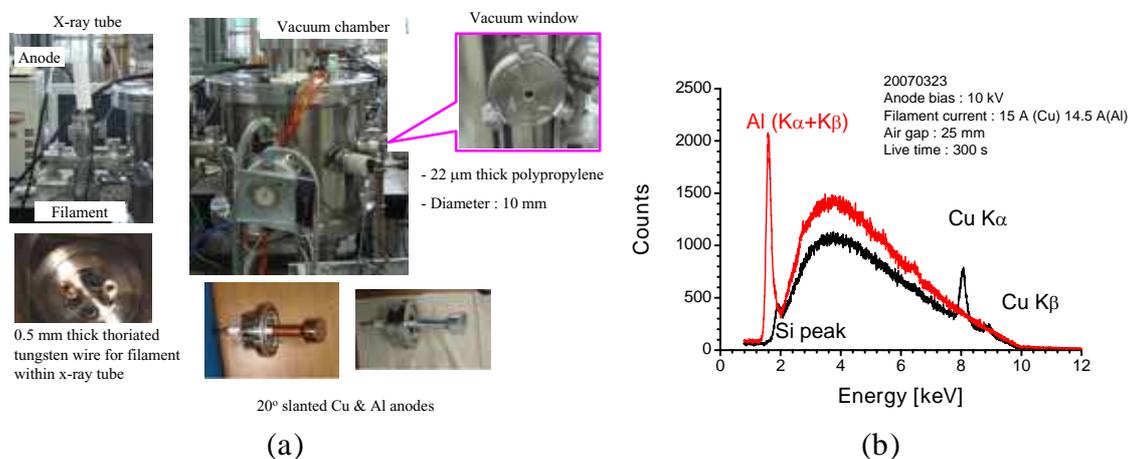


Fig. 1. Experimental set-up for the measurement of x-ray spectrum from the x-ray tube (a) and typical x-ray spectra from Cu and Al anodes (b).

In the measurement, it was found that the x-ray intensity further increased as slightly increasing the filament current and the anode bias voltage for the x-ray production, and the attenuation of the x-ray in the air gap between vacuum window and the Si(Li) detector became higher as increasing the gap distance for the case of the x-rays from the Al anode.

The x-ray tube, as a line x-ray source, is needed for the *in-situ* calibration of a two dimensional (2D) detector that is a position-sensitive, multi-wire proportional counter for the KSTAR x-ray image crystal spectrometer (XICS) [3-4]. Thus, the image characteristics of the x-ray tube are investigated by using a pinhole and the 2D detector mounted on the vacuum chamber as shown in Fig. 2(a). A Cu disc with a 0.5 mm diameter pinhole was installed at the position between the x-ray tube and the 2D detector. The distance from the x-ray tube was 25.5 cm, so the magnification of the image from the x-ray tube was 1.64 at the position of the 2 D detector. The dimension of the 2D detector, which consists of 1024 × 1024 channels, is 10 cm (in the x-axis) by 30 cm (in the y-axis). The position calibration in the 2D detector was done by using ^{55}Fe x-ray source with 50 μm slit, and the conversion factor was 0.11365 mm per channel along the x-axis. Details on the detector were described in Ref. 3. After the experiment for the investigation of the image characteristics from the x-ray tube, the image on the each anode surface is observed as shown in Fig. 2(b). The width of the image is about 1 mm for two anodes. Two anode images are a slightly curved line perpendicular to the direction of the filament in the x-ray tube.

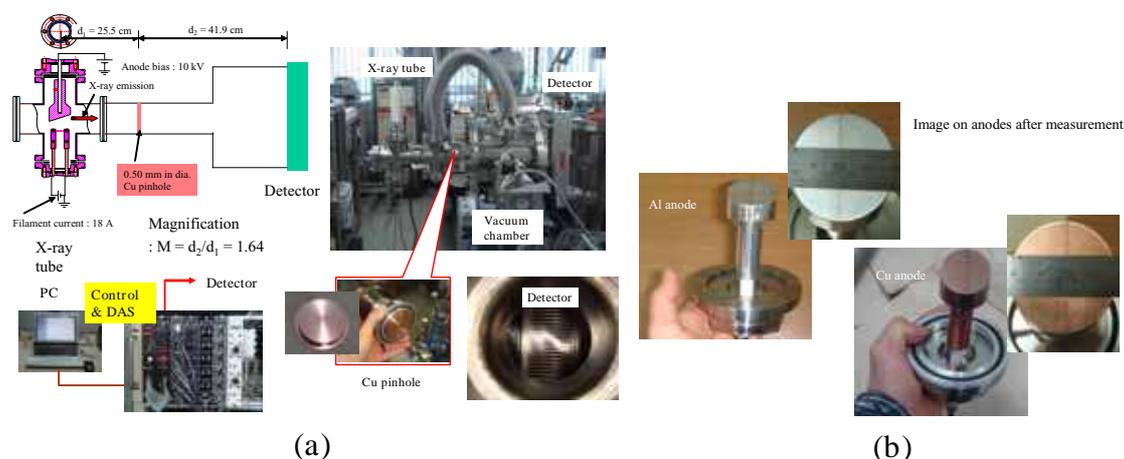


Fig. 2. Experimental set-up for the investigation of the image characteristic of the x-ray tube by using the Cu pinhole and the 2D detector (a) and the images on surfaces of the Cu and Al anodes after the experiments (b).

The images from the Cu and Al anodes are obtained from the 2D detector using the pinhole as shown in Fig. 3(a). The maximum width of each image is about 1.080 mm and 0.952 mm near the center of the image for the Cu and Al anodes, respectively. The width is equal to the FWHM obtained from the Gaussian fit for the intensity distribution along the x-axis obtained by binning the intensities in the channels along y-axis as shown in Fig. 3(b). Here, the anode bias voltage was 15 kV and the filament current was 18 A for the x-ray production. The images are slightly

curved lines, which is similar with the anode image shown in Fig 2(b). The discontinuities in the image are due to the anode wires in the 2D detector because the detection of the x-rays is inactive the region near the anode wire.

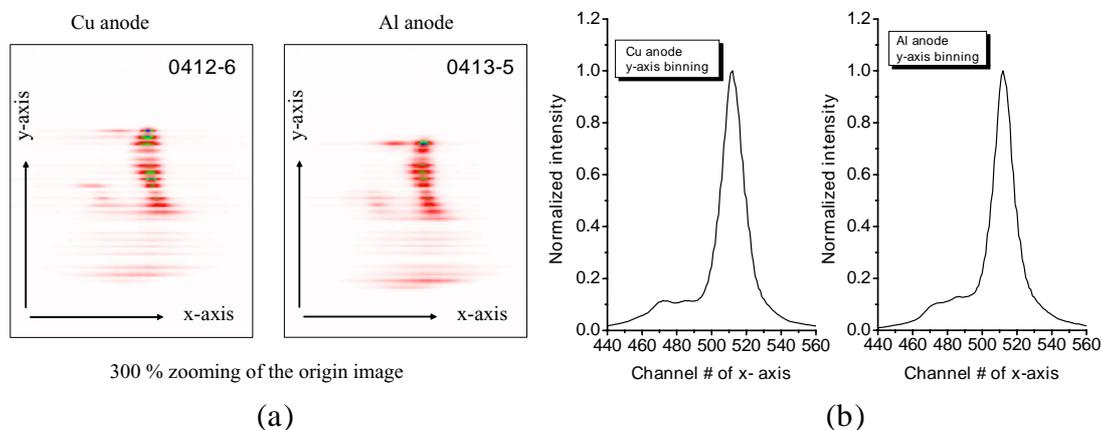


Fig. 3. X-ray images from the 20° planned Cu and Al anodes (a) and the intensity distribution of the x-rays along the x-axis from two anodes (b).

The width of the image from two anodes became narrow as increasing anode bias voltage, and the image from the Al anode had a narrower width at the same operation conditions for the x-ray production (see Table 1).

Table 1. Image characteristic for different anode bias voltages at the filament current of 18 A.

| V_{anode} [V] | Cu anode | | Al anode | |
|---------------------------|------------------|----------|------------------|----------|
| | FWHM | Position | FWHM | Position |
| 10 | 16.65 = 1.154 mm | 516.02 | 15.05 = 1.043 mm | 517.04 |
| 12 | 16.26 = 1.127 mm | 513.85 | 14.99 = 1.039 mm | 514.07 |
| 15 | 15.58 = 1.080 mm | 511.89 | 13.74 = 0.952 mm | 511.92 |

In addition, the intensity distribution along the y-axis is obtained from the image ('0413-5' in Fig.3(a)) by binning the intensities in channels in the x-direction as shown in Fig. 4(a). The dips in the intensity distribution are caused from both the reduction and the block of x-rays due to the anode wires and the supporting ribs, respectively, in the 2D detector [4]. The number of channels between two adjacent dips is six, and the distance between two adjacent anode wires was 2 mm in the 2 D detector. Thus, the channel-position in the y-axis of the 2D detector was calibrated as 0.3333 mm per channel. The total width of the distribution, which is the length of the image in the y-direction, is about 75 channels or 15.2 mm from the intensity distribution. The length of the image is also evaluated as 16.2 mm from the intensity distribution in the x-axis as shown in Fig. 4(b). Here, the image was obtained from the 2D detector after the x-ray

tube was rotated 90 degree in the clockwise. The length of the image was expected as 14.6 mm from the geometry of the anode and the filament in the x-ray tube [2].

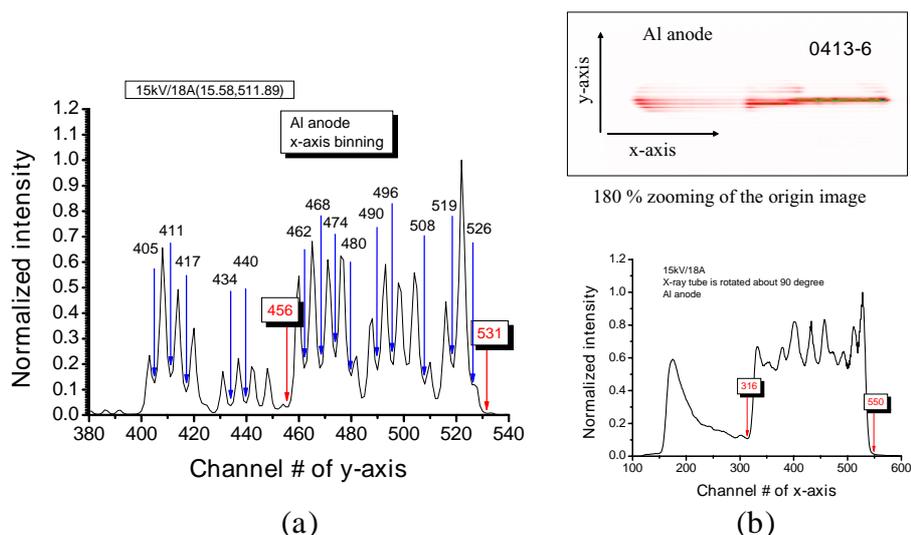


Fig. 4. Intensity distribution along the y-axis (a) and the image and the intensity along x-axis after the x-ray tube is rotated 90 degree in the counterclockwise (b).

From the experimental investigation of the x-ray image from the x-ray tube, it was found that the width of the image was about 1 mm, and the width was able to be reduced by changing the operational conditions for the x-ray production in the x-ray tube. The further study on the geometry between the filament and anode in the x-ray tube will be carried out for the improvements in the image characteristics of the x-ray tube, which is essential to get a further improved line focused x-rays for the *in-situ* calibration of the 2D detector of the KSTAR XCS.

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References

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