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Imaging performance study of the quantum X-ray scanner based on GaAs detectors

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Abstract

This work is devoted to a more detail testing of overall imaging performance of our developed digital quantum scanner. We enhanced spatial resolution in direction of detection unit movement from 254 down to 85 μm. In particular its spatial resolution, resolution in contrast and imaging ability through evaluation images, revealed with various testing objects are performed. For irradiation an X-ray tube was used. The obtained results are discussed in the scope of published results.

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Keywords: Semi-insulating; GaAs; Radiation detector; X-ray detection

1. Introduction

Digital X-ray radiography is a modern technique which provides higher sensitivity, better resolution in contrast, density profile identifying in comparison with the standard film X-ray imaging technique [1,2]. The most important ability is the detection of single photons and its energy determining. These new features can be utilized in many applications, e.g. health service, on-line process control, non-destructive material evaluation and recently growing importance of security systems. Semi-insulating (SI) GaAs is one of the most important candidates for fabrication of semiconductor X- and γ-ray detectors applicable in digital radiology instrumentations [3–5].

The aim of this work is completing our previous study of developed digital quantum X-ray scanner based on a monolithic line array of SI GaAs strip detectors [6]. We reduced the step of line detection unit about three times. Digital X-ray images were taken and the imaging performance of digital quantum X-ray scanner is analyzed.

2. Experiment and discussion

Fig. 1 shows a photo of developed digital quantum X-ray scanner and the used X-ray source ERESCO 50-200. Pictures of several testing objects (fraction of car tyre, electron tubes, and frozen chicken wing) are illustrated in Figs. 2a–c. High voltage of X-ray tube was 70 kV and current 8 mA. The image quality of car tyre and electron tubes is very satisfying. Worse result is attained for scanning of frozen chicken wing. Due to the low absorption (low contrast) the noise is much higher, but the bones of wing are clearly visible. The background of the image reveals repeated growing and falling of intensity (or total counts) in each detector pixel. The most probable reason of this effect relates to stepping motion of detection unit.

Image quality at low-dose radiation or very short scanning time demonstrates Fig. 3. The image contains vacuum electron tube EL 34, two low-voltage light bulbs, and four photolithography metal masks with different

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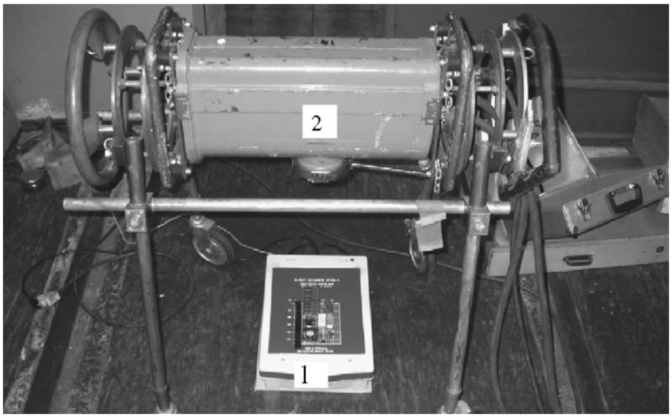

Fig. 1. Picture of developed X-ray scanner (1) with X-ray source (2) ERESCO 50-200.

Table 1
The description of X-ray scanned masks

Masks	1	2	3	4
Thickness (μm)	200	130	300	300
Diameter (mm)	0.6	0.65; 1.15	0.65	1.4

thickness and diameter of holes. Geometrical characteristics of used masks are listed in Table 1. Maximum counts for each pixel detector do not exceed value of 500. This is more than 30 times lower comparing to other showing images. The main source of noise in image is caused by fluctuation of photon generation in X-ray source. The step of strip line detectors used in former images was 254 μm.

We refined the step of detection unit in quantum digital X-ray scanner. Now, we can take images using three various steps: 254, 169, or 85 μm. The resolution in direction of strip line detectors is 250 μm (pitch of detectors). Maximum pixel resolution of images reaches 564×408 pixels. Fig. 4 shows comparison of X-ray images with 254 and 85 μm steps. Spatial resolution of image (Fig. 4b) in *Y*-direction is about three times better than *X*-direction. Brighter and darker stripes represent pad of 24 strip detectors which consist of the linear detection unit. The incident photon flux of X-ray tube is inhomogeneous and the counting rate depends on area where each detector is located. Due to this, we need to first scan X-ray source without objects (background) and subsequently subtract the X-ray image with testing samples. This was also done with presented images shown in Figs. 2–4. In the case of Fig. 4b, the artefacts are visible too. The main reason is usage of the background image scanned with 254 μm step instead of 85 μm. Due to the problems with X-ray tube, it was not possible to scan background image with 85 μm step in this case. Fig. 5 shows the image of mouse using 85 μm step of detection unit. High voltage of X-ray tube was 40 keV and flowing current 5 mA. In this case, we measure the background image (so-called fixed pattern noise) using the same step of detection unit, but the subtraction of X-ray source inhomogenity is not sufficiently exact.

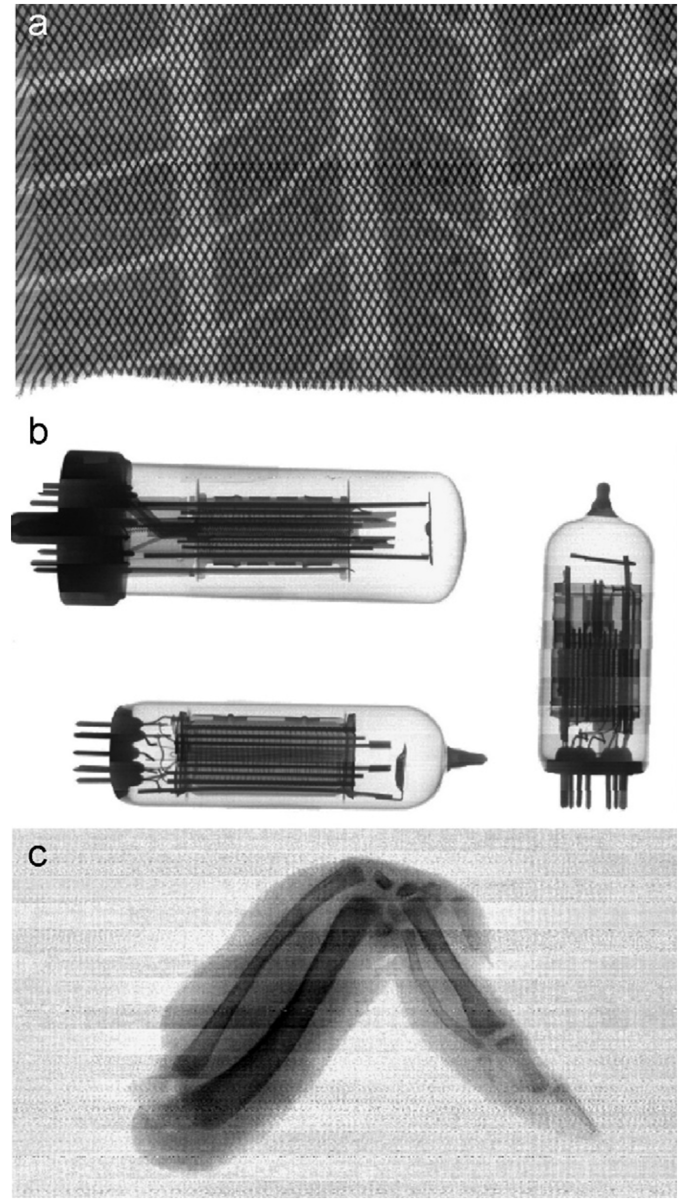

Fig. 2. Quantum X-ray images of various testing objects taken with digital scanner. (a) Fraction of car tyre; (b) electron tubes; (c) frozen chicken wing (70 kV, 8 mA, 1000 ms of one line readout).

Another problem, which cannot be neglected, is connected with using a polychromatic X-ray source and change of incident angle to detectors during the moving of detection unit on its trajectory.

Basic problem of the digital X-ray scanner is connected with fixed X-ray source. The best solution is interconnection of X-ray source with stepping moving of detection unit. As was mentioned above, the using of polychromatic X-ray source gives rise to brighter and darker stripes in the final image. One problem is related with a construction of our line detection system, which consists of 20 elements containing 24 strip line detectors. Each element is glued to aluminium (Al) holder. Because it is neccessary to keep a blank space between each element, the detection unit is ordered according to Fig. 6a. Elements with strip line