Performance characterization of large-area CMOS FPD for micro-CT applications

Soohwa Kam [a], Hosang Jeon [c], Ho kyung Kim [a,b*]
[a] School of Mechanical Engineering, Pusan National University, Busan 609-735, South Korea
[b] Center for Advanced Medical Engineering Research, Pusan National University, Busan 609-735, South Korea
[c] Department of Radiation Oncology, Pusan National University Yangsan Hospital, Yangsan 626-770, South Korea
[*] *Corresponding author: hokyung@pusan.ac.kr*

1. Introduction

Complementary metal-oxide semiconductor (CMOS) flat-panel detector (FPD) has lately attracted due to its intrinsic low additive electronic noise, high fill factor, small pixel size, and dynamic imaging capability [1], [2]. Furthermore, recent advanced technologies in a Si wafer growth and buttable detector module have overcomes the imaging detector size limitation to develop a large-area digital radiography (DR) detector.

With these advantages, the usage of the CMOS FPD for large-area x-ray detector applications (small-animal imaging, fluoroscopy, angiography, etc.) has been recently spotlighted. Although *a*-Si FPDs have many advantages such as a large imaging area, thin structure, and veiling glares, there are still some technical difficulties including relatively large pixel size and image lag to apply for a dynamic imaging applications such as a micro-CT for small-animal imaging. However, CMOS technology can be a solution for these technical limitations. Therefore, it is necessary to characterize the quantitative performance of CMOS FPD for small-animal micro-CT application. In this study, we have investigated an imaging performance of CMOS FPD. As an imaging performance metrics, sensitivity, modulation-transfer function (MTF), noise-power spectrum (NPS), and detective quantum efficiency (DQE) have been investigated.

2. Methods and Materials

2.1 Experimental Setup

Fig. 1 shows the CMOS FPD Xmaru1215CF-Master Plus^{TM} (Rayence Co. Ltd., Korea.) that we have adopted for micro-CT application. The CMOS FPD had a format of 2352 x 2944 pixels with a pitch of ~50 μm and the maximum frame rate of the detector was 8 frames per second (fps) for full-resolution mode. To convert incident x-ray photons into light photons, the FPD consisted of a CsI:Tl scintillator. Although it had various pixel binning mode, we conducted the experiment in a full-resolution mode (max. 8 fps).

Fig. 1 Photograph of Xmaru1215CF-Master Plus^{TM} CMOS FPD.

The microfocus x-ray source (Apogee^{TM}, Oxford Instruments X-ray Technology, Inc., USA) having a tungsten target, and the nominal focal spot size was 35 μm was used to mimic small-animal imaging conditions. We have used a 45 kVp x-ray spectrum which was tailored by a 2.5 mm-thick added aluminum filtration. The measured half-value layer (HVL) using a calibrated ion chamber (Piranha R&F/M 605, RTI, Electronics AB, Sweden) was 1.71 mm in an aluminum thickness.

The x-ray imaging performance of the CMOS FPD was investigated in terms of MTF, NPS and DQE which addresses the spatial resolution, noise variance and signal-to-noise ratio respectively with the procedure recommended by IEC report [4].

2.2 Detective quantum efficiency

DQE as a function of a spatial frequency, which includes combined MTF and NPS, is a key factor to assess the quality of an imaging detector. The spatial frequency dependent DQE can be defined as the ratio of squared signal-to-noise ratio (SNR) at output and input stage:

$$\mathrm{DQE}(u) = \frac{\mathrm{SNR}^2_{\mathrm{out}}(u)}{\mathrm{SNR}^2_{\mathrm{in}}(u)} = \frac{\bar{q}\bar{G}^2\,\mathrm{MTF}^2_{\mathrm{out}}(u)}{\mathrm{NPS}_{\mathrm{out}}(u)},$$

where $\bar{q}$ is the incident photon fluence (quanta/mm^{-2}) and $\bar{G} = \bar{d}/\bar{q}$ is the system gain where $\bar{d}$ is the pixel value of output images in digital unit [4], [5].

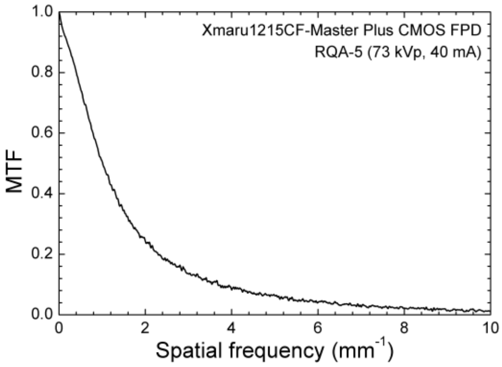

Fig. 2 Measured MTF for the Xmaru1215CF-Master Plus™ CMOS FPD with CsI:Tl scintillator. The MTF at Nyquist spatial frequency was ~0.01 for RQA-5.

3. Preliminary result and Summary

Fig. 2 shows the measured MTF of Xmaru1215CF-Master Plus™ CMOS FPD under the RQA-5 standard radiation quality for chest radiography. The MTF at Nyquist spatial frequency (10 lp/mm^{-1}) was ~ 0.01.

In this study, we have investigated the imaging performance of the Xmaru1215CF-Master Plus™ CMOS FPD for small-animal micro-CT application. We expect that the MTF is promising for high-resolution imaging application. Although the detector has not been optimized for small-animal applications, these performance evaluation will be useful for the feasibility validation of CMOS FPD as a small-animal imaging detector. Detailed result such as the sensitivity, MTF, NPS, and DQE for small-animal imaging will be announced later.

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REFERENCES

[1] N. Matsuura, W. Zhao, Z. Huang, and J. A. Rowlands, "Digital radiology using active matrix readout: Amplified pixel detector array for fluoroscopy," *Med. Phys.*, vol. 26, pp. 672-681, 1999.
[2] H.K. Kim, G. Cho, S.W. Lee, Y.H. Shin, and H.S. Cho, "Development and evaluation of a digital radiographic system based on CMOS image sensor," *IEEE Trans. Nuc. Sci.*, vol. 48, pp. 662-666, 2001.
[3] S.C. Lee, H. K. Kim, I.K. Chun, M.H. Cho, S.Y. Lee, and M.H. Cho, "A falt-panel detector based micro-CT system: Performance evaluation for small-animal imaging," Phys. Med. Biol., **48**(24), 4173-4185, 2003.
[4] IEC 62220-1-3: Medical electrical equipment-Characteristics of digital X-ray imaging devices-Determination of the detective quantum efficiency, International Electrotechnical Commission (IEC), Geneva, Switzerland, 2008.
[5] H.K. Kim, S. M. Yun, J.S. Ko, G. Cho, and T. Graeve, "Cascade modeling of pixelated scintillator detectors for x-ray imaging, "IEEE Trans. Nucl. Sco., **55**(3), 1357-1366, 2008.