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Micro-angiographic Fluoroscope

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***Abstract*— X-ray and radionuclide imaging are popular modalities for medical imaging. Different types of detectors are normally used for different types of imaging. In this paper, we have reviewed a detector capable of both fluoroscopy and angiography, to be used as an imager for both single-photon and integral-energy imaging and applied to the dual modalities of radionuclide imaging and X-ray imaging. The micro-angiographic fluoroscope (MAF) has 1024x1024 pixels of 35 m effective size and has the capability of real-time imaging at the rate of 30 fps. The large variable gain of its light image intensifier (LII) provides quantum-limited operation without any instrumentation noise. We reviewed that the MAF can be operated in single-photon counting (SPC) mode. SPC mode of X-ray imaging gives better resolution than energy integration (EI) mode. Improved spatial resolution in SPC mode compared to EI mode can be seen in the images of line-pair phantom. The MAF operation in SPC mode for radionuclide imaging using a custom-built phantom filled with I-125 is also included.An integrated frame was obtained in the SPC mode by summing up multiple single-thresholded frames which were acquired at a rate of 20 fps. Human phalanges X-ray was taken in SPC and EI mode and the SPC mode proved to be superior. The dual mode of MAF operation makes it more versatile for use**

***Index Terms*— detector, fluoroscope, phantom, radionuclide, resolution**

I. INTRODUCTION

A micro-angiographic fluoroscope (MAF) is a replacement for lower resolution full field view X-ray detectors. Instead of full view, MAF provides high resolution in region of interest. Latest MAF is an indirect X-ray imaging detector; it provides real time images (30 frames per second). Image array is 1024x1024 pixels with effective pixel size of 35 microns. It has(MAF)[1] superior clinical imaging capabilities; hence the images are characterized with high resolution, high sensitivity, no lag and low instrumentation noise[1], [2].The MAF detector is uniquely capable of two modes of operation:

1) Conventional Energy Integrator (EI) and

2) Single Photon Counting(SPC).

HD Mode of MAF:

HD mode of MAF is preferred since it enables detailed features of endovascular devices like stent struts to be visualized clearly for the first time. It provides improved image quality. It provides small focal spot effectively improving contrast to noise ratio (CNR) and spatial resolution. When a bar phantom was used with images taken in HD mode for CNR and resolution evaluation with both MAF and Flat Panel Detector(FPD), it was observed that FPD could resolve maximum 2.8 lp/mm whereas MAF could resolve 5 lp/mm. At lower frequencies CNR of MAF was better than FPD by 60% and at Nyquist frequency it was better by 600%.

Radionuclide Imaging:

The image can be generated by processing frames acquired in SPC mode by keeping the collimator stationary. During the experimental setup, if there is non-zero distance (not in contact with each other) between the collimator and the detector due to which event profiles from adjacent collimator holes overlap each other and give higher count in the septal region. Fig. 1 shows transmission X-Ray image of the radionuclide phantom acquired by the MAF.

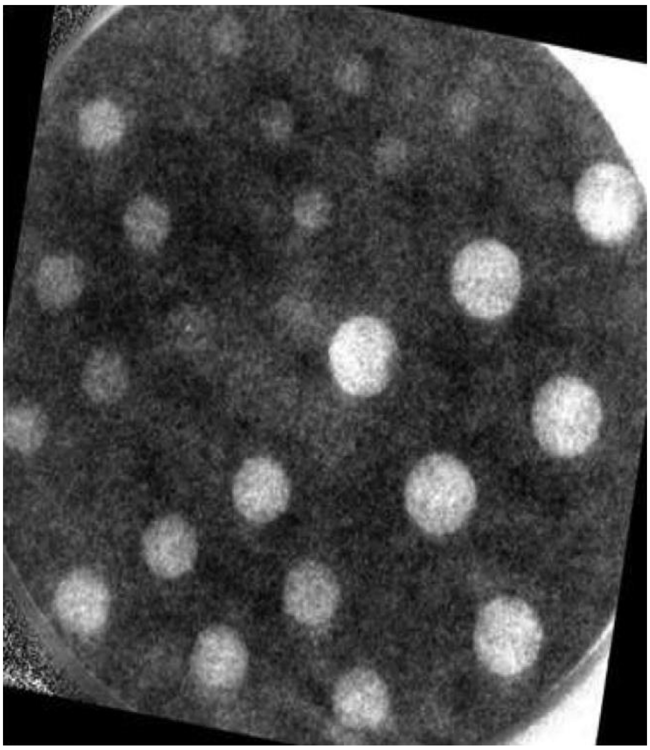

Fig. 1. Transmission X-Ray image of the radionuclide phantom acquired by the MAF[3].

II. COMPONENTS OF HD MODE OF MAF

The MAF detector is schematically shown in Fig. 2. MAF is CCD based x-ray detector. The CCD camera is a 1024×1024 array of 12 µm size pixels. A 300 µm thick structured CsI(Tl) is coupled to a Gen 2 Dual Microchannel Plate LII. Because

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of the LII the camera has a large variable gain. The LII is coupled to the CCD camera through a 2.88:1 ratio fiber optic taper and thus gives MAF an effective pixel size of 35 µm

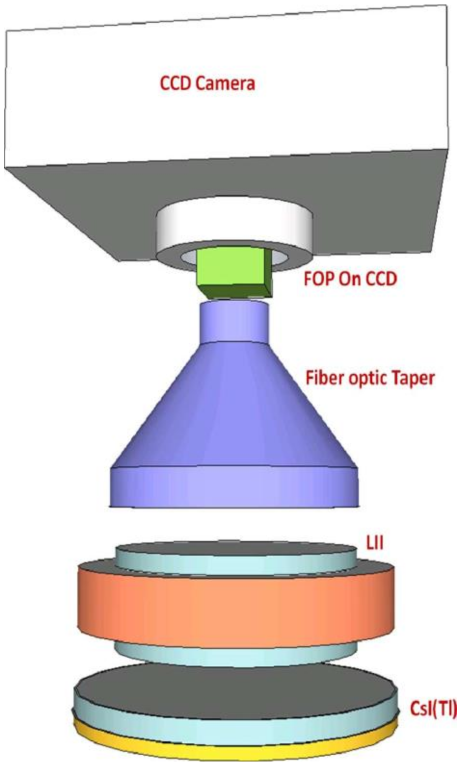

Fig. 2. Schematic diagram of MAF

As shown in Fig. 3 the CCD camera (DALSA 1M30) [4] is coupled to generation-2 dual micro-channel plate (MCP) light image intensifier (Model PP0410K) [5] through 2.88 fiber optic taper. LII is coupled to 300 micrometer thick CsI (T1) scintillator [6] through fiber option plate. LII provides variable gain and hence MAF easily operates as quantum-noise-limited detector for fluoroscopy and angiography. To improve thresholding effectiveness, monochromatic X-ray spectrum is used for transmission imaging SPC mode. Generation of this spectrum can be done by adding 15 mm iodine contrast media having density 350 mg/ml which is an additional filtration to a 50-kVp X-ray beam from clinical c-arm system (Infinix). Shape of the spectrum is calculated using SRS-78 X-ray spectrum generation software [7].

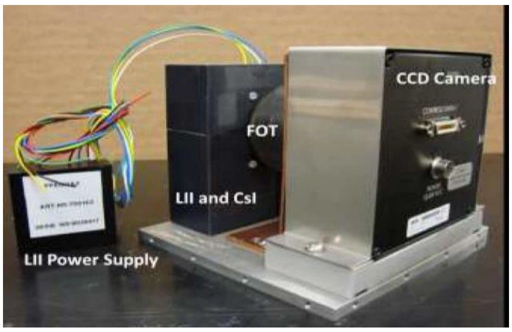

Fig 3. Micro angiographic Fluoroscope[3].

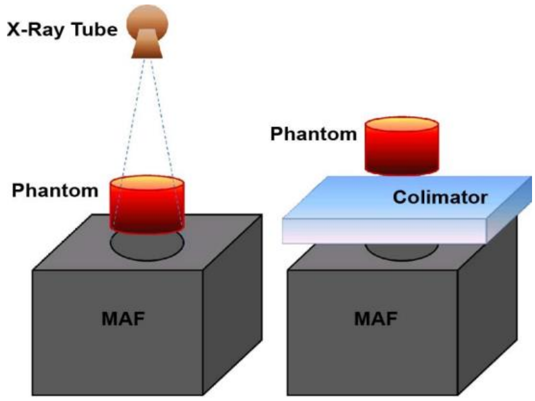

Fig 4. Experimental set up diagram for (left) X-ray Imaging amd (right) Radionuclide Imaging[3].

Hot-rod phantom is used for evaluation of SPC emission. The white circles represent cylindrical cavities in a plastic insert as solid colour as shown in figure. This insert is placed in a cylindrical container that is filled with solution containing 1 mCi of 125I. Diameter of phantom is 3.5 cm. Depth of hot rods is about 2 cm. Medium energy parallel-hole gamma camera collimator with lead septa and holes of 1mm diameter and 24.5mm height that was available to us. The CsI in the MAF was about 10mm from the outer surface of the collimator, so the estimated collimator resolution was 1.24mm for an object at its surface. For X-Ray imaging set in both the modes, no gamma-camera collimator is used and the phantoms are placed near the detector as shown in Fig. 4. For radionuclide imaging collimator is placed between the phantom and MAF as shown in Fig. 4.

III. WORKING

A. X-Ray imaging in EI and SPC Mode:

Various calculations are made to determine the number of absorbed X-Ray photons per pixel frame and the total count expected. There is an example for calculation for the slit image. The number of x-ray photons per frame for the slit image can be calculated knowing the slit area. Once the number is known, an appropriate threshold value is applied to get an approximate count number which is close to the calculated one, and then the frames are summed to form the SPC mode image.

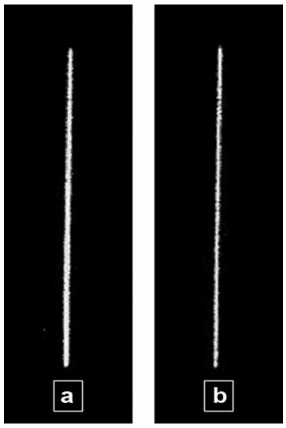

Fig 5.Slit images for (a) energy integrating mode and (b) single photon counting mode[3].

The slit images taken in energy integrating and single photon counting mode are shown in the Fig. 5. These slit images were used to calculate the modulation transfer function (MTF) using slanted slit method [8]. Threshold selected for slit images was applied to form SPC image of the line-pair phantom and the human phalanges bone.

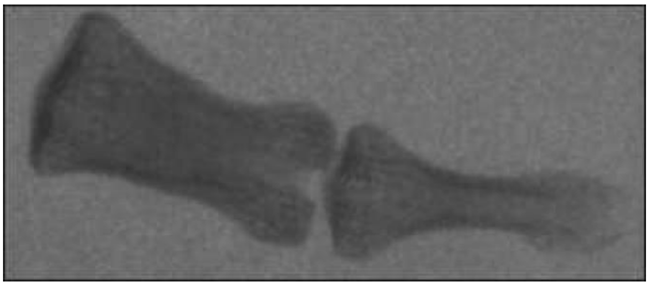

Fig 6. Human Phalanges Bone images taken with EI mode[3].

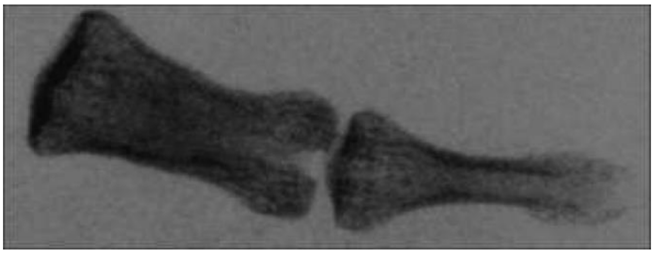

Fig 7. Human Phalanges bone images taken with SPC mode.[3].

In Fig. 6 and Fig. 7 contrast improvement of human phalanges bone is given with visual demonstration of SPC mode over EI mode.

IV. ADVANTAGES OF SPC MODE OVER EI MODE

LII gain with very low exposure (<1 x-ray photon/pixel) per frame was used for SPC mode and LII gain with higher exposure per frame and lower gain was used for EI mode. A heavily K-edged x-ray beam with average energy of 31 keV was used to provide monochromatic spectrum. MTF measured using standard slit method showed dramatic improvement for SPC mode over EI mode at all frequencies. Images of line pair phantom showed spatial resolution with 12 lp/mm in SPC mode and only 8 lp/mm for EI mode. The advantages of SPC mode are useful for clinical applications where high resolution and/or high contrast are essential such as in mammography and also for dual modality applications, which combine nuclear medicine and x-ray imaging using single detector. The advantages of SPC mode over EI mode have been confirmed by a qualitative comparison of contrast between the two modes was made by imaging human distal and middle phalanges bones of pinky finger from hand skeleton embedded in plastic.

V. SUMMARY AND COMPARISONS

Due to the slit image taken in SPC mode a visually sharper and a better resolution image is obtained then that of EI mode. SPC mode has higher (qualitative) contrast with very fine details of the image than that of EI mode. In this study a quasi monochromatic spectra is used as only a simple threshold technique to detect the events. Various other better and complex techniques such as Centroid detection can be used to detect the event more accurately with the original information being retained[9]-[11].Here as low energy isotope is used , CsI is just 300 micrometer thick; if we replace it with 1000 micrometer then high energy isotopes can be used to achieve a better absorption efficiency.

VI. CONCLUSION

The The MAF detector provides real-time image guidance with the help of two of its modes SPC mode and EI mode. It provides required high sensitivity X-Ray imaging capabilities with a considerable increase in spatial resolution.

It is shown that the SPC mode shows a very high contrast with higher resolution which is a key factor in X-Ray imaging.

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