Development of a small field of view gamma camera for medical imaging

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Aims and objectives

The development of small field of view (SFOV) gamma cameras for intraoperative imaging is an expanding area of research. The Hybrid Compact Gamma Camera (HCGC) combines gamma and optical imaging in a co-aligned configuration to provide high spatial resolution imaging for bedside and surgical procedures [1].

The purpose of this study was to compare the performance of the HCGC following the experimental protocols developed by the Institute of Physics and Engineering in Medicine (IPEM) [2] using two thicknesses of columnar thallium doped caesium iodide CsI(TI) scintillators. Characteristics investigated include: intrinsic spatial resolution, system spatial resolution and system sensitivity.

Methods and materials

The Hybrid Compact Gamma Camera (HCGC) is a new technology, developed in the Space Research Centre, University of Leicester in collaboration with Nottingham University Hospitals, for hybrid gamma-optical imaging (figure 1).

A performance characterisation of the HCGC has been completed using 600µm and 1500µm CsI(TI) scintillators.

Intrinsic spatial resolution

To measure the intrinsic spatial resolution a 10mm thick lead block with a slit of 2mm width and 20mm length positioned on top of the un-collimated camera. A 2mm diameter 20MBq ^{99m}Tc point source was placed at a distance of 250mm above the surface of the slit. A slit image produced for 10000 frames by the HCGC with both scintillators see (figures 2 and 3).

System spatial resolution

To measure the system spatial resolution a 1.1mm diameter line source of 30MBq ^{99m}Tc was imaged with both 0.5mm and 1.0mm diameters pinhole collimators. Layers of Perspex starting from 5mm thickness up to 40mm were placed between the collimator and the source. Images produced for 3000 frames by the HCGC with both scintillators see (figures 4 and 5).

System sensitivity

To measure the system sensitivity, a 20MBq ^{99m}Tc point source was placed at a fixed distance of 250mm away from the surface of the un-collimated camera with increasing layers of Perspex (ranging from 0-40 mm) on top of the source. Images acquired for 5000 frames by the HCGC with both scintillators see (figures 6 and 7). The sensitivity was calculated by dividing the total recorded counts by the incident counts on the detector. The incident counts were calculated using the solid angle, the known activity of the source, the distance to the detector and the detector size.

Images for this section:

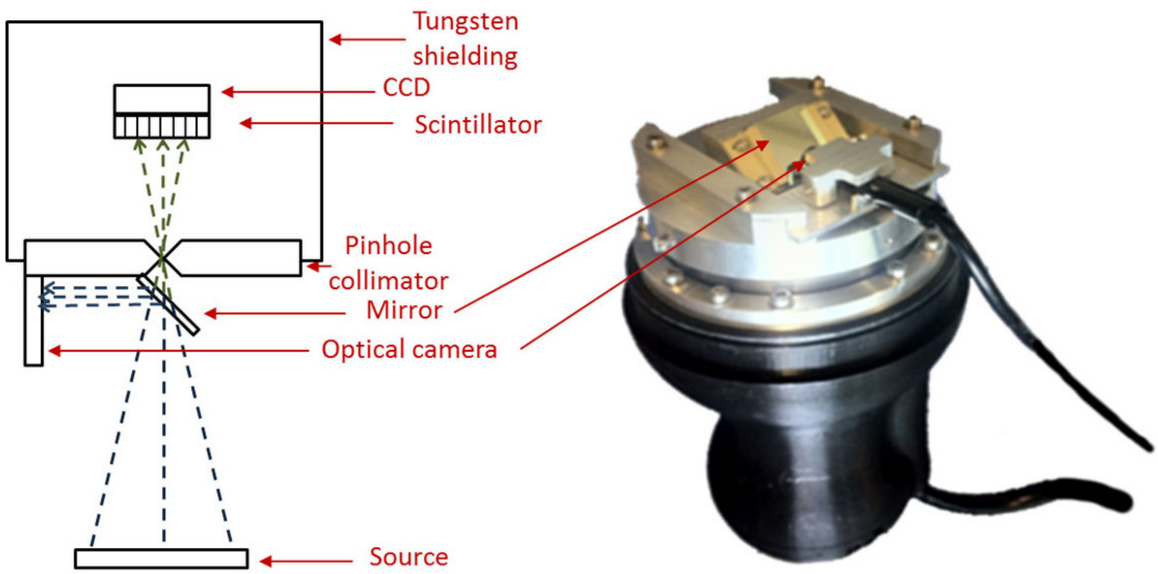

Fig. 1: Left: Schematic diagram of Hybrid Compact Gamma Camera HCGC. Right: Image of HCGC.

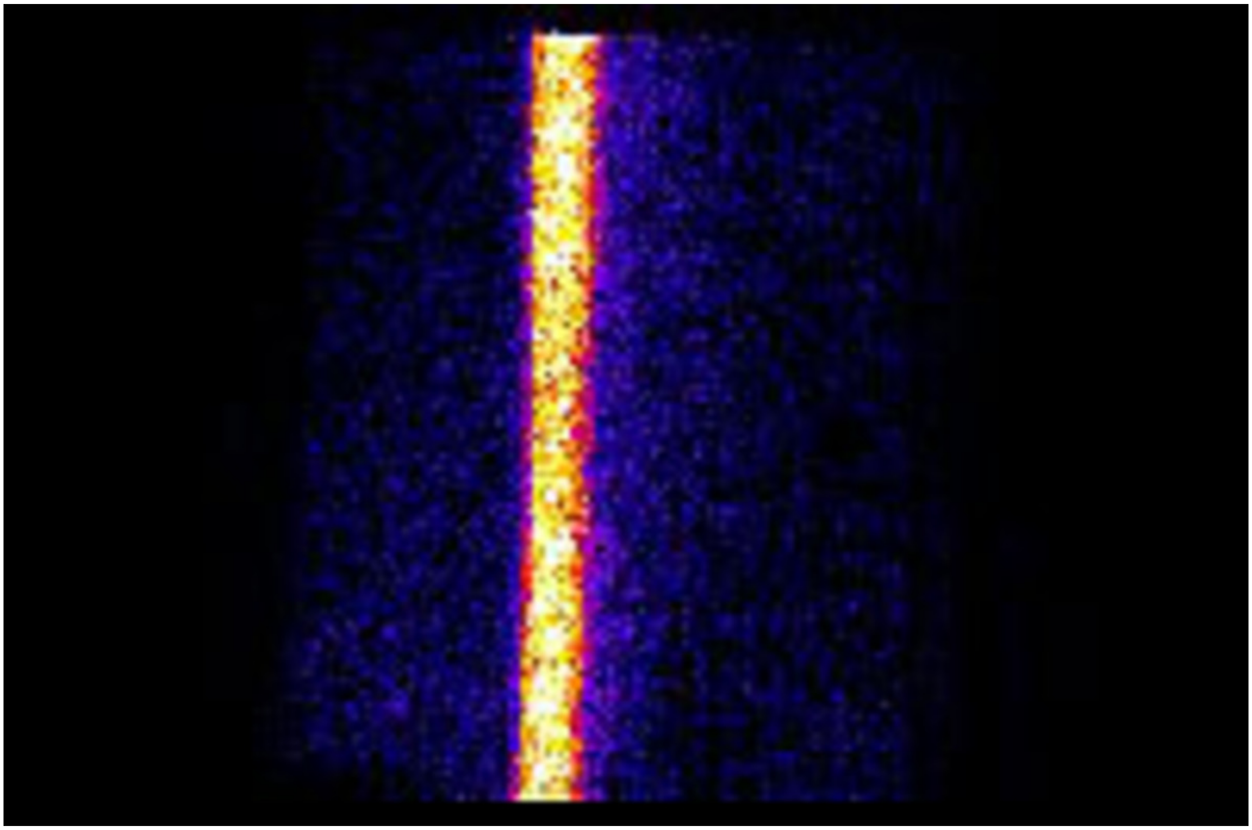

Fig. 2: Final image of 20MBq Tc-99m source at 250mm distance from the 2mm width slit, with 600µm CsI(TI) scintillator for the intrinsic spatial resolution measurement. Total no. of frames was 10000.

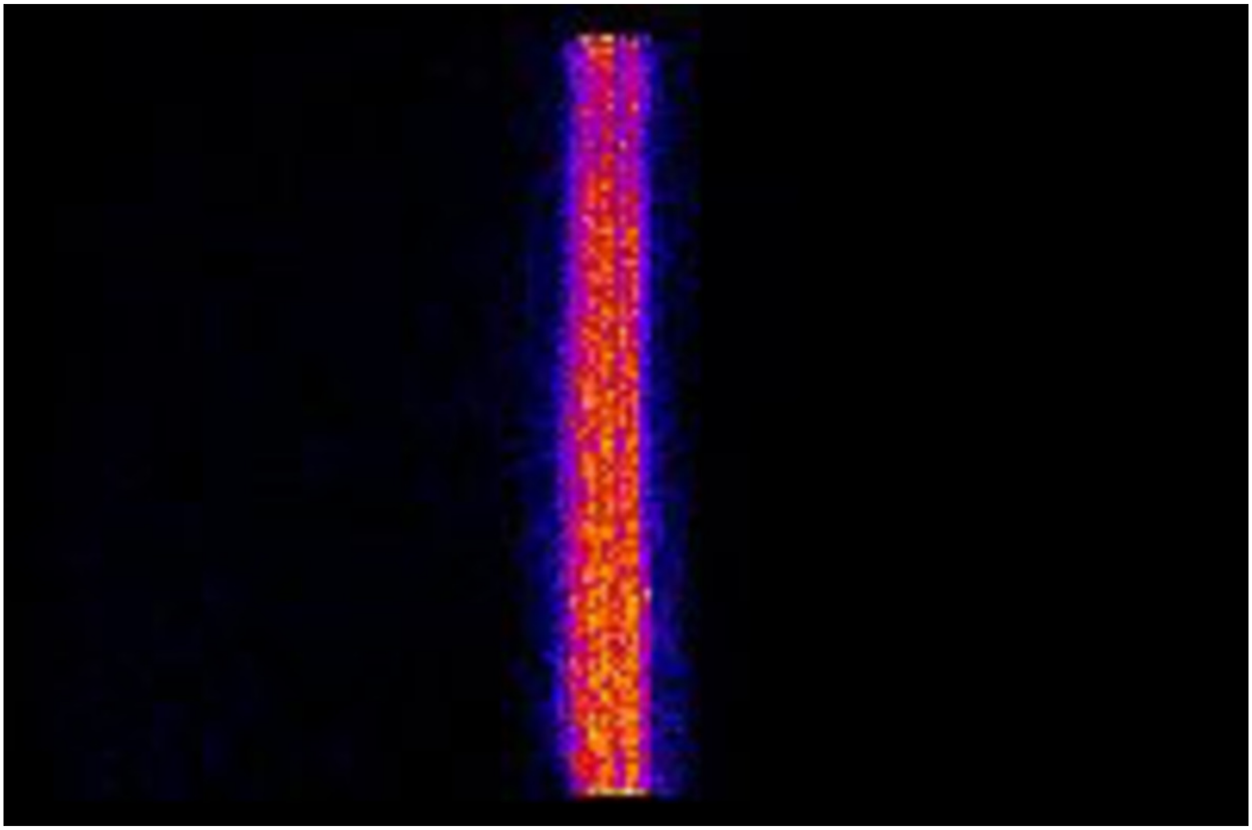

Fig. 3: Final image of 20MBq Tc-99m source at 250mm distance from the 2mm width slit, with 1500µm CsI(TI) scintillator for the intrinsic spatial resolution measurement. Total no. of frames was 10000.

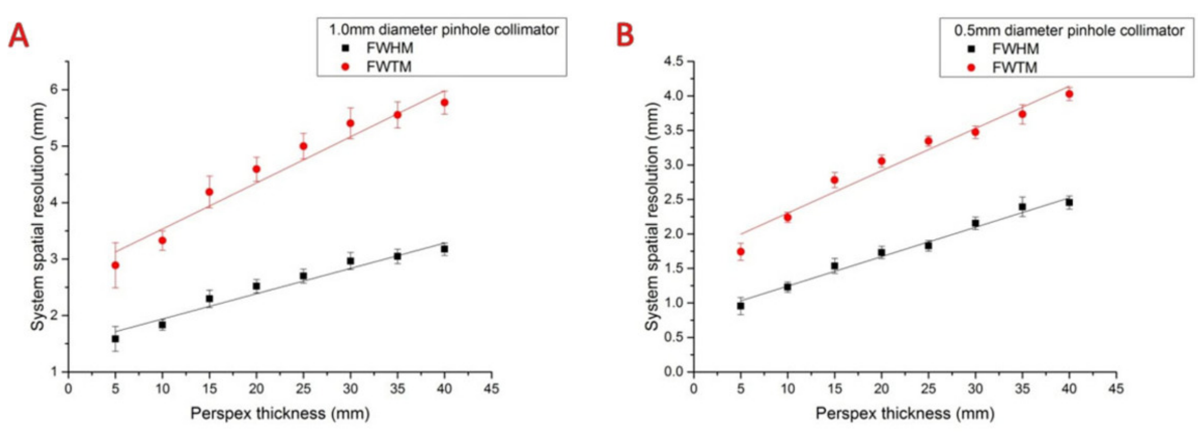

Fig. 4: Graphs showing the system spatial resolution vs Perspex thickness. FWHM (black square) and FWTM (red dots) calculated for 1.1mm diameter cannula filled with 30MBq Tc-99m which was used as a line source with 600µm CsI(TI) scintillator using pinhole collimator. A) 1.0mm diameter pinhole collimator. B) 0.5mm diameter pinhole collimator. No. of frames 3000.

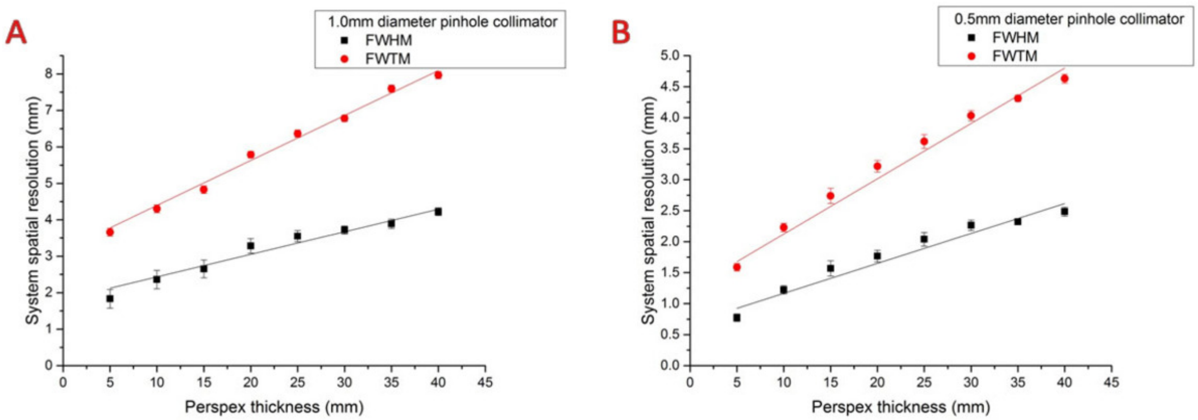

Fig. 5: Graphs showing the system spatial resolution vs Perspex thickness. FWHM (black square) and FWTM (red dots) calculated for 1.1mm diameter cannula filled with 30MBq Tc-99m which was used as a line source with 1500µm CsI(TI) scintillator using pinhole collimator. A) 1.0mm diameter pinhole collimator. B) 0.5mm diameter pinhole collimator. No. of frames 3000.

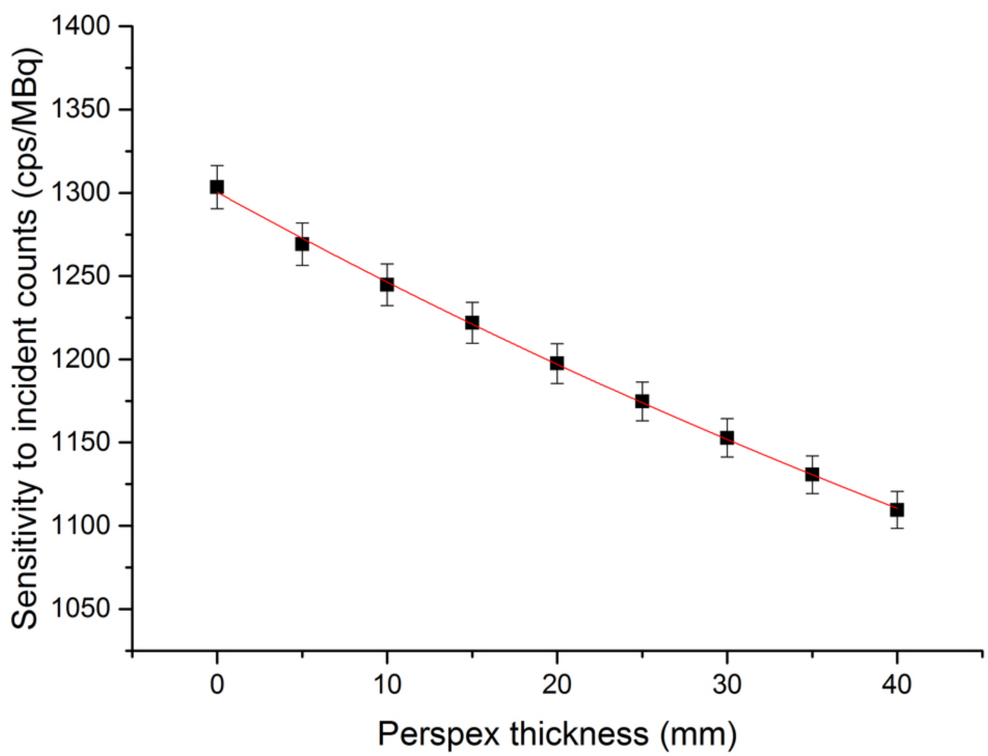

Fig. 6: A 20MBq Tc-99m point source placed at 250mm away from the HCGC with increasing layers of Perspex added in between to show the relationship between the intrinsic sensitivity of the HCGC and the Perspex thickness with 600µm CsI(TI) scintillator.

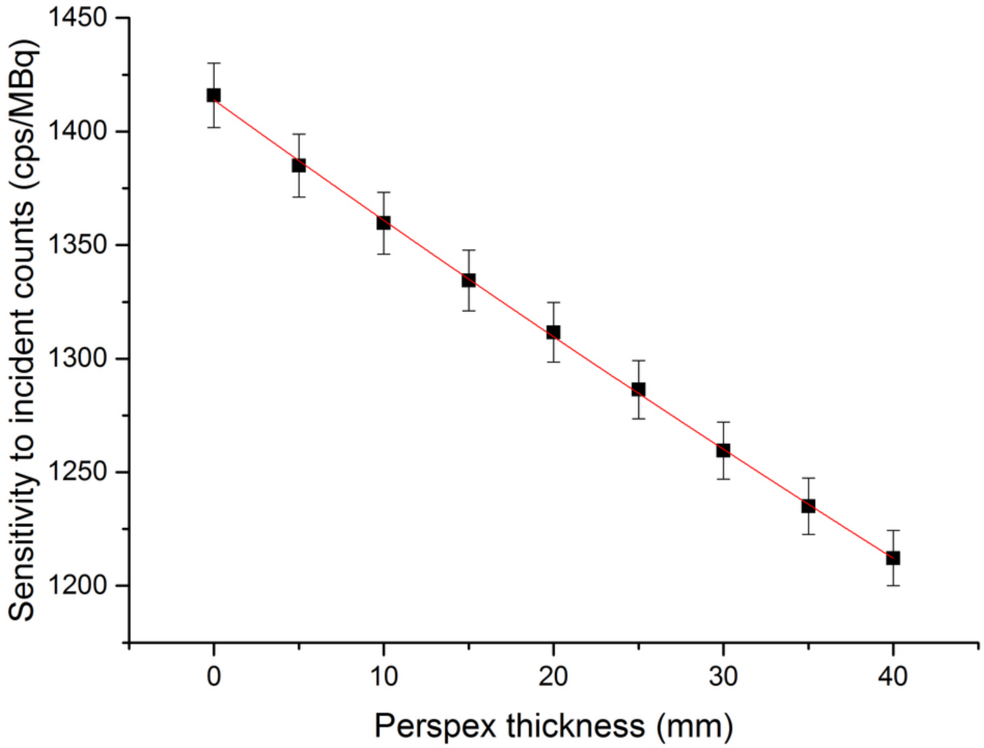

Fig. 7: A 20MBq Tc-99m point source placed at 250mm away from the HCGC with increasing layers of Perspex added in between to show the relationship between the intrinsic sensitivity of the HCGC and the Perspex thickness with 1500µm CsI(TI) scintillator.

Results

Table 1 contains the measured performance characteristics for the intrinsic spatial resolution of the HCGC with both CsI(TI) scintillators 600µm and 1500µm.

Table 2 contains the measured performance characteristics for the system spatial resolution of the HCGC with both CsI(TI) scintillators 600µm and 1500µm.

Table 3 contains the theoretical and the experimental performance characteristics for the system sensitivity of the HCGC with both CsI(TI) scintillators 600µm and 1500µm.

Comparing the intrinsic spatial resolution of the HCGC with 600µm and 1500µm CsI scintillators shows that the 600µm thickness operates with better intrinsic and spatial resolution. Therefore it is better at distinguishing objects. In measuring system sensitivity it was found that using ^{99m}Tc source with energy of 140keV with both 600µm and 1500µm CsI scintillators, the sensitivity were approximately 19% and 30% respectively.

Images for this section:

CsI scintillator	FWHM (mm)	FWTM (mm)
600µm	0.30±0.04	0.56±0.04
1500µm	0.32±0.05	0.58±0.05

Table 1: Intrinsic spatial resolution result for Tc-99m.

CsI scintillator	Pinhole collimator	FWHM (mm)
600µm	0.5mm	1.20±0.08
	1.0mm	1.94±0.14
1500µm	0.5mm	1.20±0.15
	1.0mm	2.43±0.25

Table 2: System spatial resolution result for Tc-99m.

CsI scintillator	Theoretical sensitivity	Experimental sensitivity
600µm	24%	19%
1500µm	49%	30%

Table 3: System sensitivity result for Tc-99m.

Conclusion

The measured characteristics of the HCGC indicate that it may have advantages for use in a range of healthcare applications such as small organ imaging and surgical investigation. These studies encourage us to carry out further evaluation in preparation for clinical use. The results indicate that there is a small degradation of spatial resolution by using a thick scintillator i.e 1500µm. However, the system sensitivity can be doubled. That means the thicker scintillator can offers better sensitivity but lower spatial resolution. Further work will be undertaken to test the HCGC with a gadolinium oxysulfide (GOS) pixelated scintillator to make a comparison between the GOS and the currently used CsI(TI) (figure 8).

Images for this section:

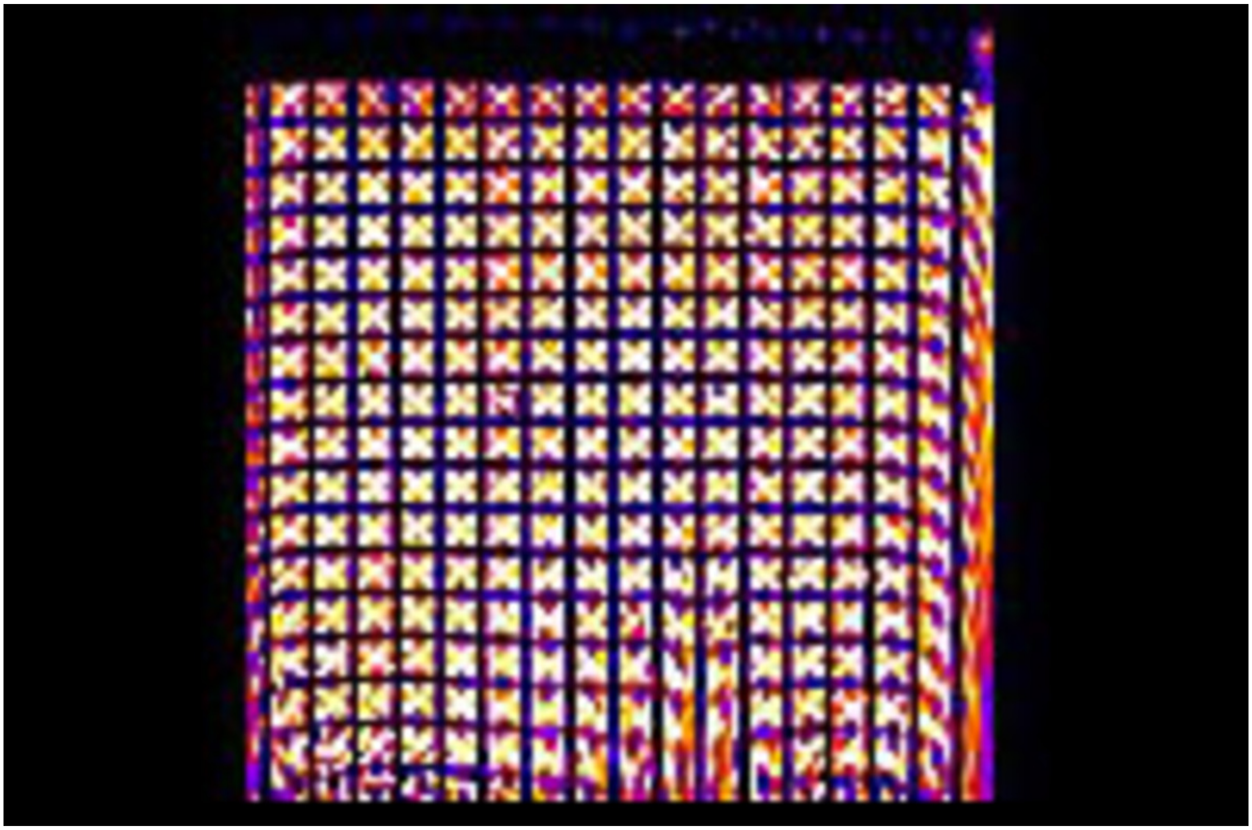

Fig. 8: A raw flood image of a 20MBq Tc-99m point source, 3mm diameter, placed at 250mm away from the un-collimated camera with GOS scintillator. No. of frames 30000.

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References

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