Advancements in Coded Aperture Imaging for 3-D Position Sensitive CZT Detectors

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Introduction and Motivation

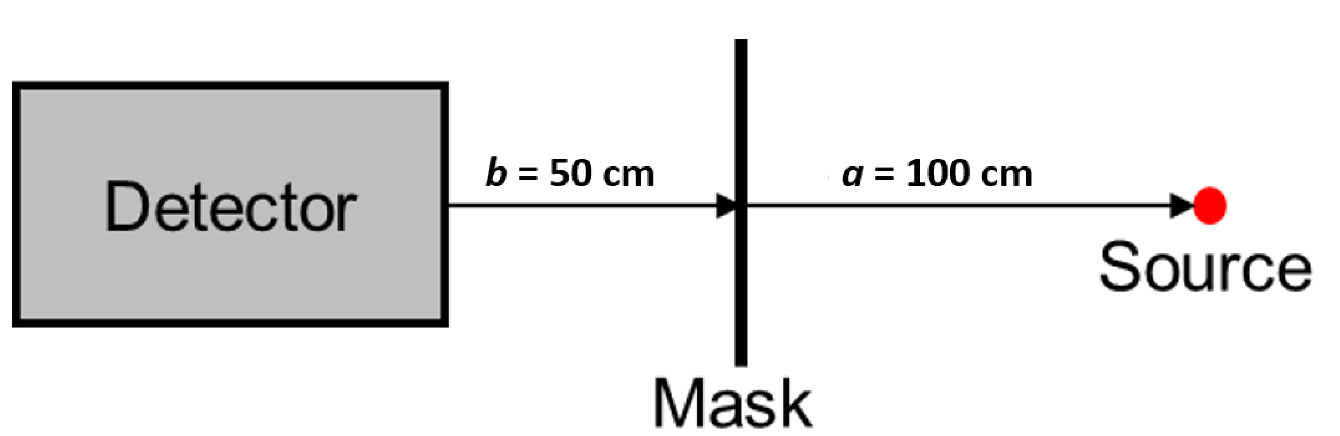
This work aims to show the advancements of coded aperture imaging for 3-D position-sensitive CdZnTe detectors. The coded aperture system uses multi-layered MURA masks made of tungsten to block low-energy gamma rays.

Mission Relevance

Improving position resolution has relevance to multiple sectors in the nuclear field. The primary sectors that these coded aperture advancements are being applied to are security by imaging special nuclear materials and medical imaging, specifically for SPECT imaging.

Technical Approach

This detector that the coded aperture mask is being designed/optimized for is a single CdZnTe crystal that is 40 mm x 40 mm x 15 mm and has a 22 × 22 pixelated anode array with a 1.77 mm pitch and a planar cathode. Utilizing subpixel resolution, the detector position resolution is approximately 0.35 mm. It is important that the magnified shadow cast by the mask aligns perfectly with the face of the detector to avoid artifacts and get the best image resolution. The size the mask shadow casts on the detector is dependent on the mask-to-detector distance (*b*) and the source-to-mask distance (*a*).



Example experimental setup used for simulations with a mask-to-source distance of 100 cm and detector-to-mask distance of 50 cm.

Imaging special nuclear material 1 m away from the detector setup is of interest so one coded aperture mask was designed with this constriction. In addition, a second mask was designed for a source infinitely far away.

The smaller the pitch (the size of the holes) of the mask's shadow the more precise the image resolution will be, so the smallest mask pitch manufacturable of 0.44 mm was chosen as another constraint.

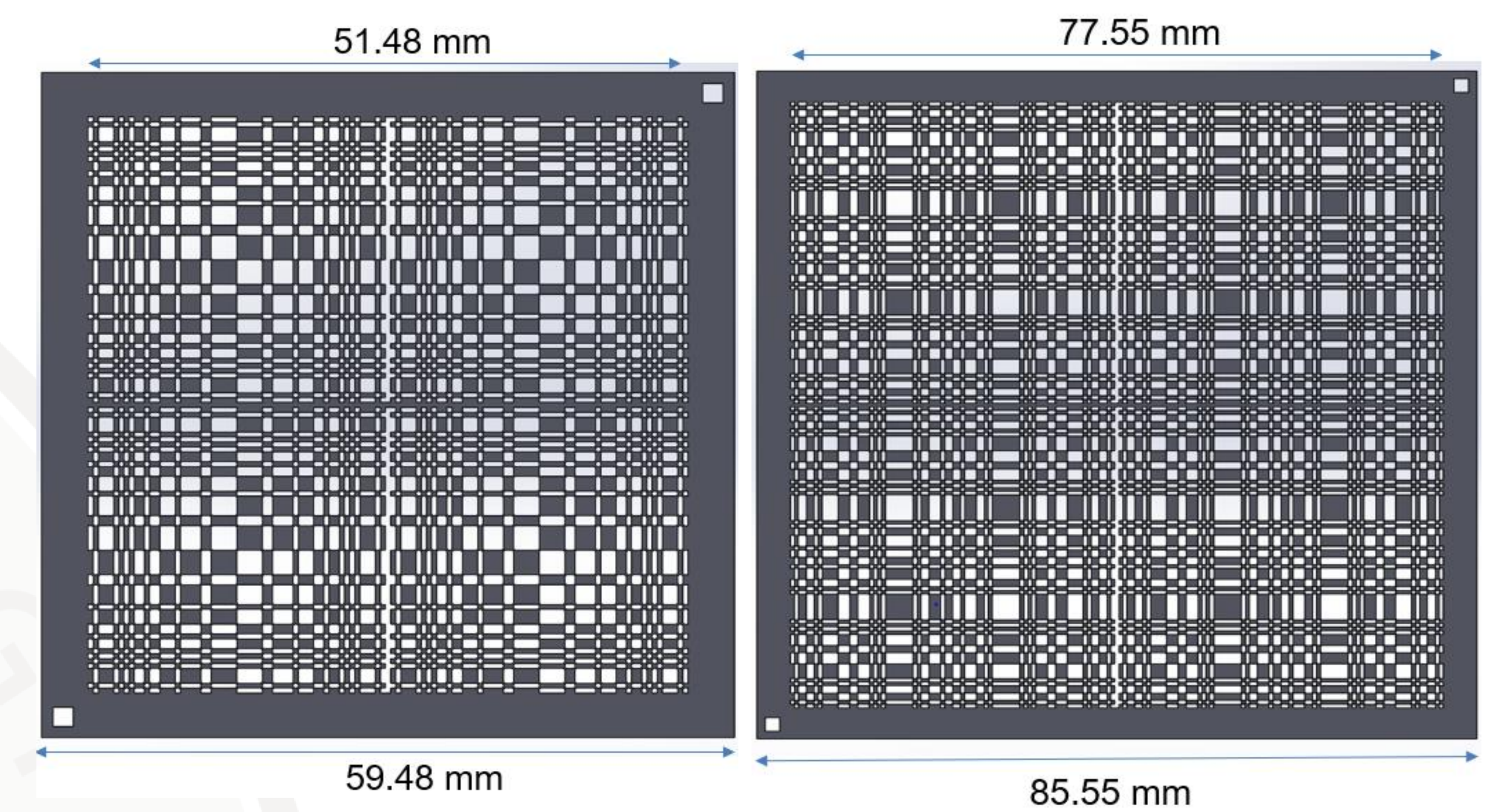
Results

From the above constraints a variety of detector-to-mask distances and mask ranks (number of holes in the mask) were simulated. A rank 59 mask with a pitch of 0.44 mm was chosen for the source-to-detector distance of 1 m and a detector-to-mask distance of 50 cm. A rank 83 mask with a pitch of 0.47 mm was chosen for the source infinitely far away. The resulting field of view for the source also played a large impact in determining the final mask designs.

Coded Aperture Mask Pitches (cm)

Rank	Detector-to-Mask distance (cm)							
	0	2	3	5	10	20	50	88
23	1.69	1.66	1.64	1.61	1.54	1.41	1.13	0.90
47	0.83	0.81	0.80	0.79	0.75	0.69	0.55	0.44
59	0.66	0.65	0.64	0.63	0.60	0.55	0.44	0.35
73	0.53	0.52	0.52	0.51	0.48	0.44	0.36	0.28
79	0.49	0.48	0.48	0.47	0.45	0.41	0.33	0.26
83	0.47	0.46	0.46	0.45	0.43	0.39	0.31	0.25
89	0.43	0.43	0.42	0.42	0.40	0.36	0.29	0.23

Table of the pitch needed to have the magnified shadow of the mask fall perfectly on the detector based on a given Rank (number of holes in the mask) and detector-to-mask distance assuming a source-to-mask distance of 100 cm. This information can also be used to determine the field of view for the various experimental setups.



A model of the two mask designs created. The Rank 59 mask (left) has a pitch of 0.44 mm and is designed for a source 1 m from the detector setup. The rank 83 mask (right) has a pitch of 0.47 mm and is designed for a source infinitely far away.

Impact

The new detector system will allow for better source position reconstruction. This will be great for more accurately determining special nuclear material location and for determining tumor location accurately with SPECT measurements. Once complete the detector system will hopefully be tested at national labs on radiation signature training devices.

Conclusion and Next Steps

These masks are currently being fabricated. Once complete they will be used to experimentally test image resolution. From there, a detector using an array of these large crystals will be created with a new corresponding coded aperture mask to increase the source field of view. The primary goal of this work is to demonstrate a resolution close to 1 mm with the detector setup 1 m away from the source. This technology will then be extended to other fields as well, such as medical imaging.

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