

# Alignment of CdTe semiconductor modular detectors for computed tomography

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**Purpose:** When CdTe semiconductor detectors are used in a CT system, we have to align many small detector modules and make a large field-of-view (FOV). In this case we have to take care of the spaces between the modules. These spaces are required for wire bonding in mounting the modules on a PCB. The purpose of this study is to evaluate the effect of these spaces and the alignment of the modules on an x-ray CT image. **Method:** We assumed a CdTe modular detector with a size of 8.0mm x 8.0mm, and by aligning many modules with the tilting angles of 0 or 14 degrees we enlarged the effective FOV. For these two configurations we evaluated images reconstructed after correcting the spaces with a linear interpolation method. **Results:** The results of simulations showed that the spaces in the modular detector degraded the quality of reconstructed images, and the tilted mounting reduced the artifacts due to the spaces compared with the horizontal mounting. **Conclusion:** We evaluated the effect of the spaces required for a modular semiconductor detector and the alignment of the modular detector.

**Keywords:** CdTe detector, interpolation, computed tomography, modular detector

## 1. Introduction

### 1.1 Semiconductor detectors for x-ray CT system

CdTe semiconductor detectors<sup>1,2</sup>, which work at room temperature, have characteristics of high energy resolution and high spatial resolution. But it is very difficult to make a uniform monolithic semiconductor detector, because the sensitivity of each pixel depends on a bonding process of tiny pixel electrodes to the ASICs<sup>3</sup>. Moreover, it is difficult to make a large crystal due to manufacturing issues, and as a result, we have to enlarge the active area of the detector by combining many modules. In this case we have to consider spaces between the modules for a wire bonding in mounting the modules on a PCB. Such spaces are inactive areas that can detect no photon. Thus, to reconstruct high quality x-ray CT images with these modular detectors, it is necessary to minimize the spaces and interpolate them with an appropriate method. In this paper we evaluated the effect of these spaces and the alignment of the modules in an x-ray CT system.

### 1.2. Detector model

In this study we assumed a CdTe modular detector that consisted of 40 x 40 pixels (pixel size: 0.2 mm x 0.2 mm), and by aligning many modules we extended the effective field of view. The size of the active area of the module was 8.0 mm x 8.0 mm, and we added a space for wire bonding to the PCB on one of the four sides with a width of more than 1.2 mm, and that on two other sides (upper and lower) with a width of 0.5 mm for manufacturing purpose. The geometry of a module is shown in Fig. 1. Two alignments of the modules are shown in Fig. 2. The setting angles of mounted modules were assumed to be 0 (horizontal mounting) and 14 degrees (tilted mounting). For these two configurations we acquired projection data and reconstructed images with and without correction of the spaces. We adopted a linear interpolation method to fill out the missing pixel values. The details of these interpolation methods are shown in Figs. 3 and 4. These methods slightly differ in terms of the pixel positions used in the linear interpolation.

## 2. Simulation and Results

Hot-rod and cold-rod phantoms (Fig. 5) were used to evaluate the effect of the spaces and the alignment of the modules. The simulation conditions are shown in Table 1. Fig. 6 shows ideal images reconstructed with a filtered back projection (FBP) method with complete projection data. The reconstructed images and the differential images that were subtracted from the corresponding ideal image are shown in Figs. 7 and 8. Fig. 7 shows the results of hot-rod phantom

image and Fig. 8 those of cold-rod phantom image.

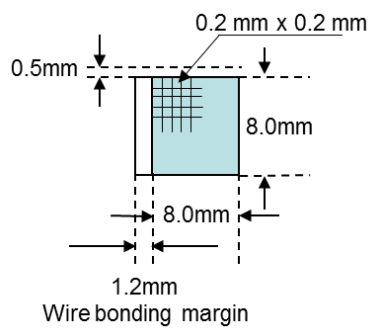


Figure 1. Geometry of a module.

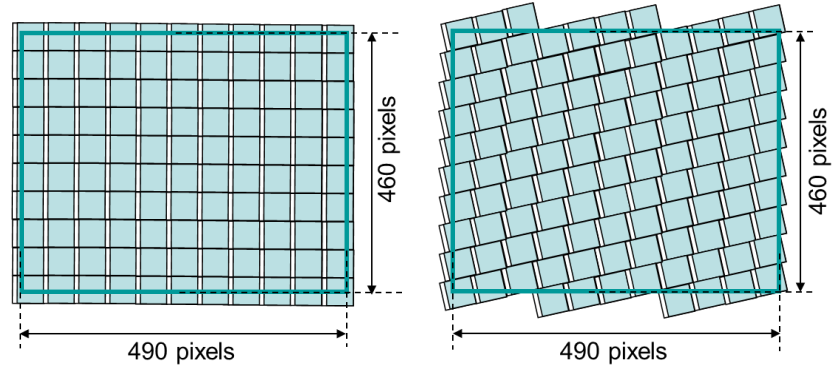
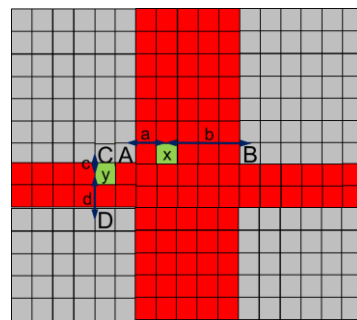


Figure 2. Alignment of modules.  
(left: horizontal mount, right: tilted mount)

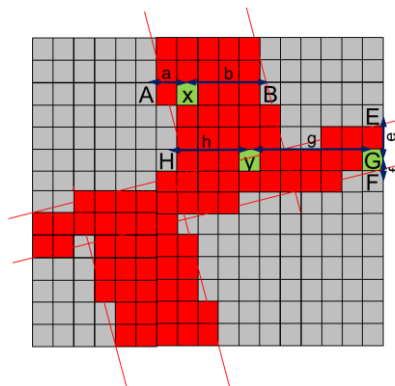


$$P(x) = \frac{a \cdot P(B) + b \cdot P(A)}{a + b} \quad (1)$$

$$P(y) = \frac{d \cdot P(C) + c \cdot P(D)}{c + d} \quad (2)$$

$P(z)$  : pixel value at position  $z$

Figure 3. Interpolation method for the horizontal mounting of modules.



$$P(x) = \frac{a \cdot P(B) + b \cdot P(A)}{a + b} \quad (3)$$

$$P(G) = \frac{f \cdot P(E) + e \cdot P(F)}{e + f} \quad (4)$$

$$P(y) = \frac{h \cdot P(G) + g \cdot P(H)}{g + h} \quad (5)$$

$P(z)$  : pixel value at position  $z$

Figure 4. Interpolation method for the tilted mounting of modules.

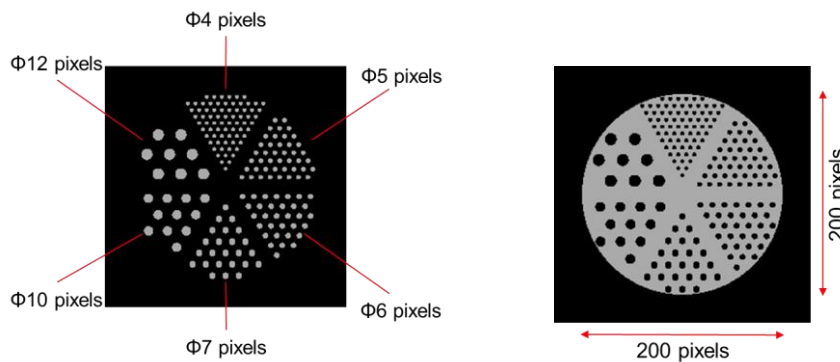


Figure 5. Numerical phantoms.  
(left: hot-rod phantom, right: cold-rod phantom)

### 3. Discussion

The reconstructed images with a large space were degraded when the space increased, while at the same time the contrast of the small rods decreased. And the amount of artifacts also increased along with the increase of the spaces. The artifact in the image using the tilted mounting was smaller than that with the horizontal mounting. We surmised that the positions of the spaces in the horizontal mounting were fixed. On the other hand, those in the tilted mounting varied, as a result of which the effect of the spaces was scattered all over the reconstructed image.

### 4. Conclusions

The spaces in a modular type detector degraded the quality of reconstructed images, and the effect of the spaces increased when the spaces increased in size. Regarding the alignment of the modules, the tilted mounting reduced the effect of the spaces compared to the horizontal mounting.

### References

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Figure 6. Ideal images reconstructed with complete projection data. (left: hot-rod phantom, right: cold-rod phantom)

Table 1. Simulation conditions.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Mount angle of modules (degree)	0	0	0	14	14	14
Lateral space (mm)	1.2	1.6	2.0	1.2	1.6	2.0
Longitudinal space (mm)	0.5	0.5	0.5	0.5	0.5	0.5

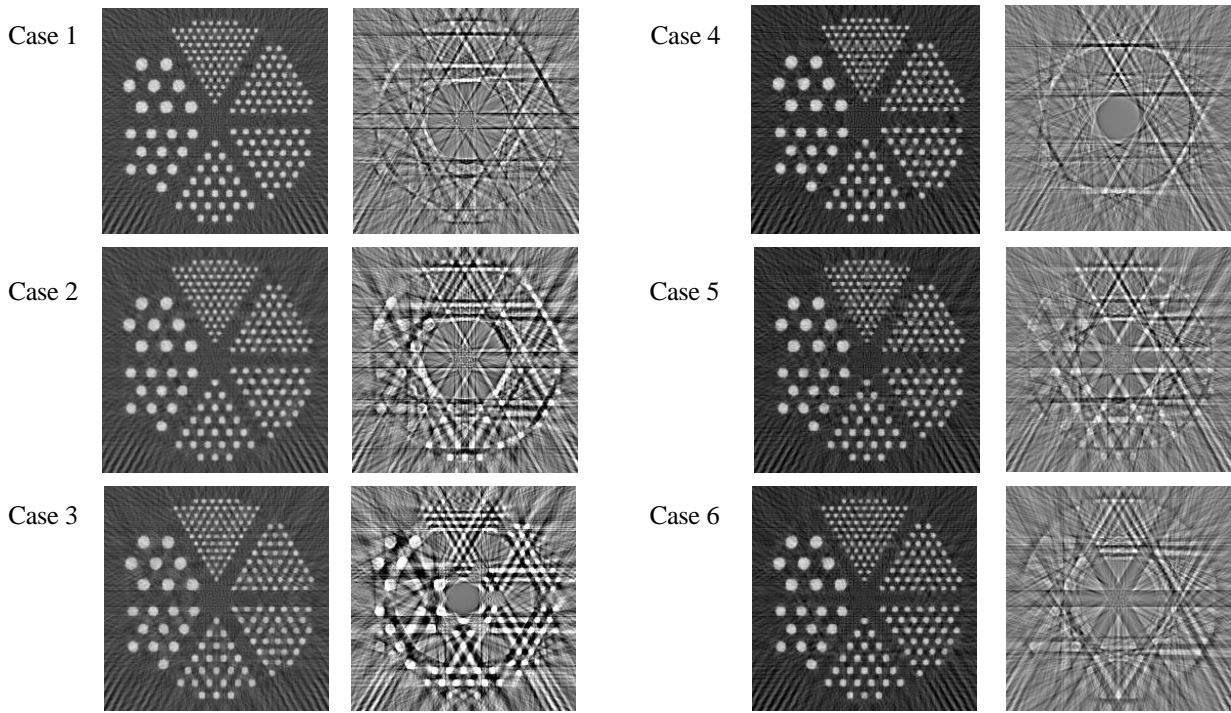


Figure 7. Hot-rod phantom reconstructed images (left) and the differential images (right) in a column.

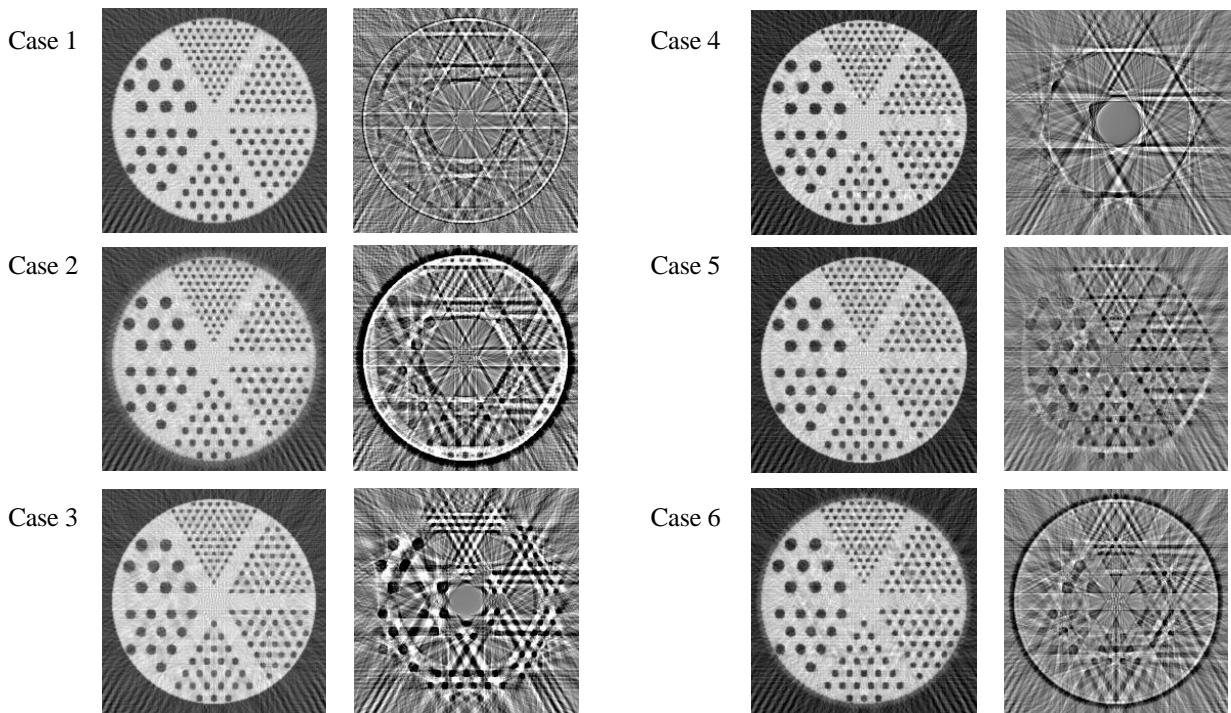


Figure 8. Cold-rod phantom reconstructed images (left) and the differential images (right) in a column.