Collimator Response along and across mask coding directions, Effects of Mask Ribs and Window Support Rods

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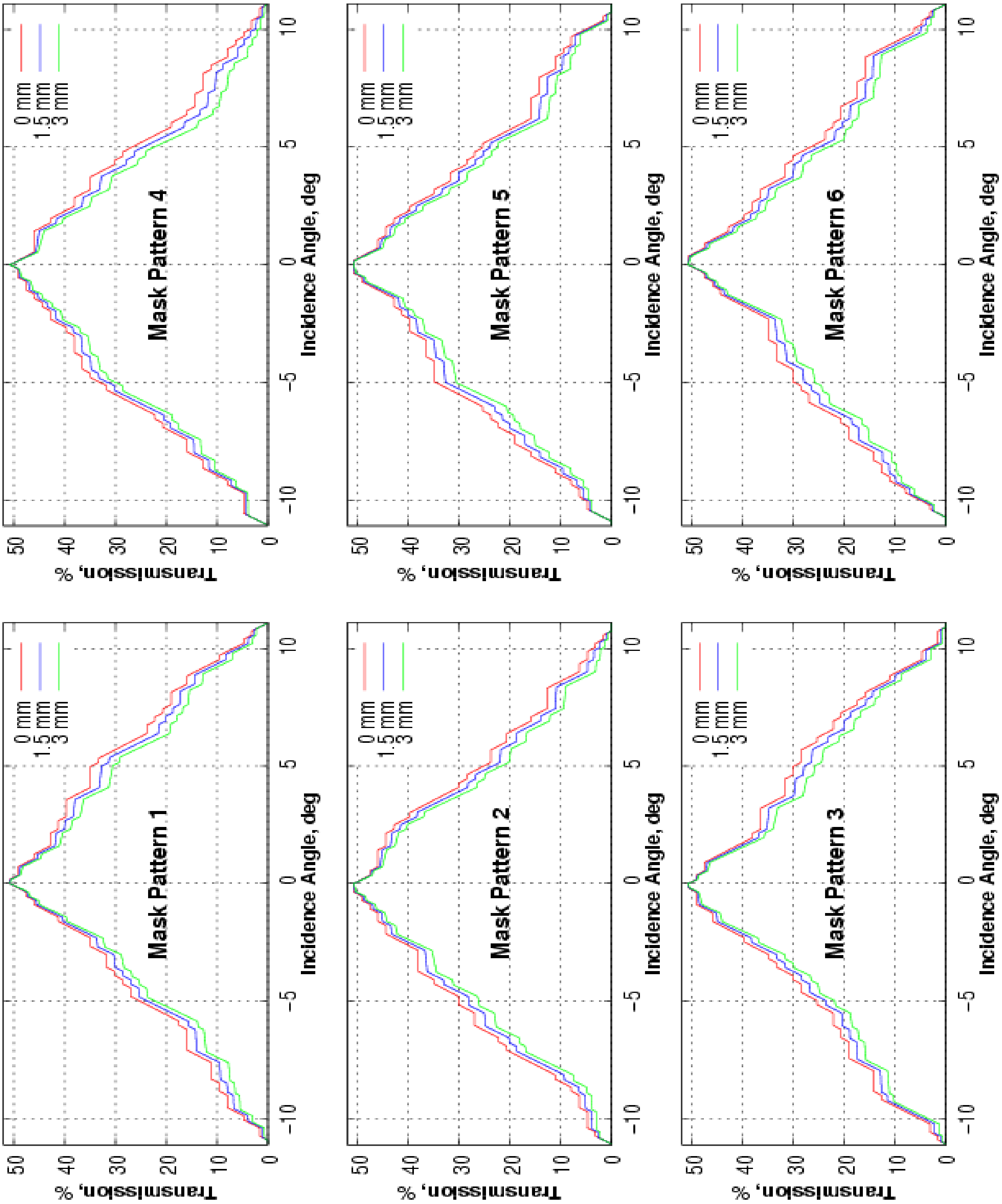
Abstract

The collimator response of the Scanning Sky Monitor (SSM) aboard ASTROSAT along and across its mask coding directions are shown in this report. The effects on imaging due to the support structures like the intra-pattern ribs, inter-pattern gaps, inter-pattern ribs, external ribs and the window-support rods have also been discussed.

Thickness of mask pattern

In the graphs shown, transmission through the mask plate as a function of the incidence angle is plotted for each of the six mask patterns. To plot these, a mask plate width of 60 mm along the mask coding direction and a height (between the



mask plate and the detector plane) of 306.5 mm have been assumed.
The red curve in each of the six panels is for a mask plate of 0 mm thickness, blue for 1.5 mm and green for 3 mm thickness.
An excerpt from the data points (used for the plots) for an incidence angle of 6.51° is shown in the table below. The numbers quoted in the boxes are the values of transmission (as a fraction of total mask area) through the mask plate.

	Mask Plate thickness = 0 mm	Mask Plate thickness = 1.5 mm	Mask Plate thickness = 3 mm
Mask Pattern 1	23.81%	21.53%	19.24%
Mask Pattern 2	19.46%	17.75%	16.04%
Mask Pattern 3	22.64%	20.64%	18.64%
Mask Pattern 4	15.87%	13.30%	10.74%
Mask Pattern 5	15.87%	14.16%	12.45%
Mask Pattern 6	20.63%	18.92%	17.21%

A similar table for an incidence angle of -6.51° is shown below:

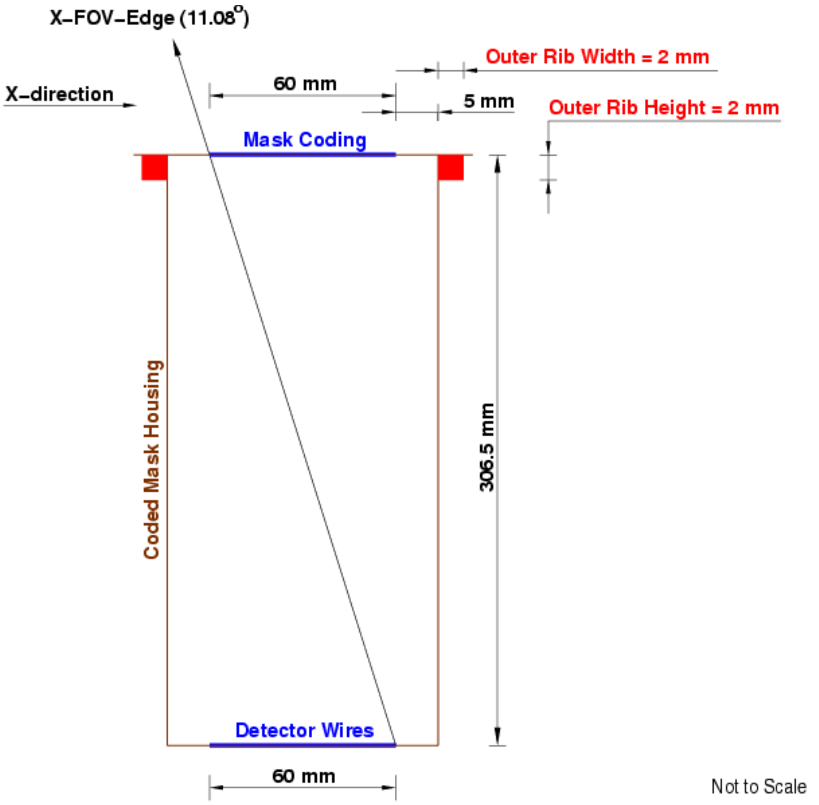
	Mask Plate thickness = 0 mm	Mask Plate thickness = 1.5 mm	Mask Plate thickness = 3 mm
Mask Pattern 1	15.87%	14.16%	12.45%
Mask Pattern 2	22.64%	20.64%	18.64%
Mask Pattern 3	20.63%	18.92%	17.21%
Mask Pattern 4	22.22%	20.51%	18.80%
Mask Pattern 5	23.81%	21.53%	19.24%
Mask Pattern 6	21.05%	19.05%	17.05%

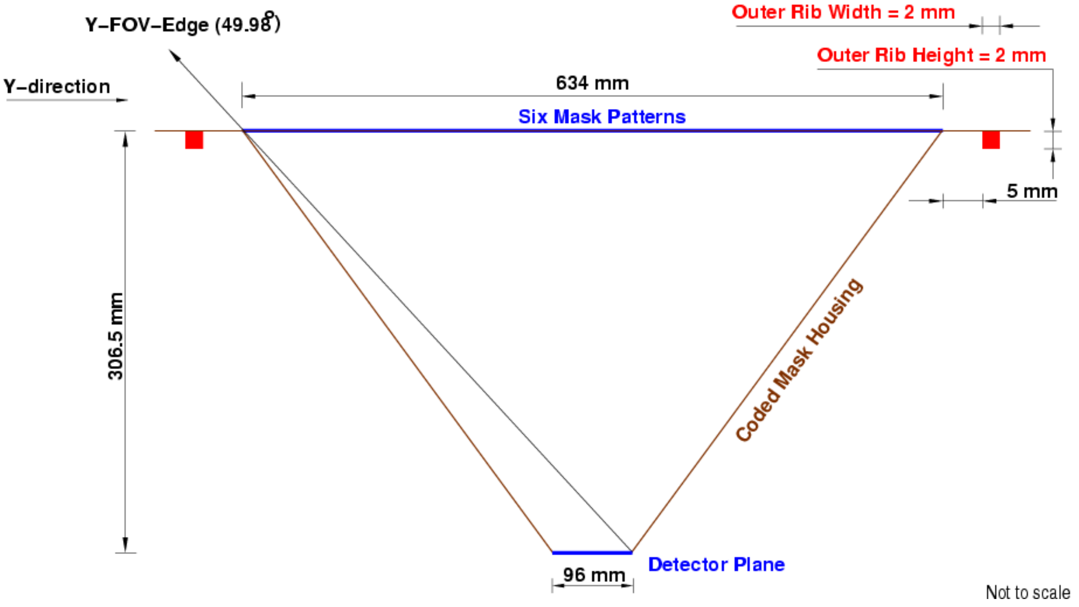
A mask plate of thickness 1.5 mm appears to have a transmission which is higher by ~ 2% when compared to that for a 3 mm thick mask plate near the half maximum points.

The outer ribs

The outer rib is assumed to be of thickness 2 mm and height 2 mm. These ribs are proposed to be placed 5 mm away from the mask-coding edge.

The following figures show the arrangement of the outer-ribs along and across mask coding directions (X and Y directions respectively).

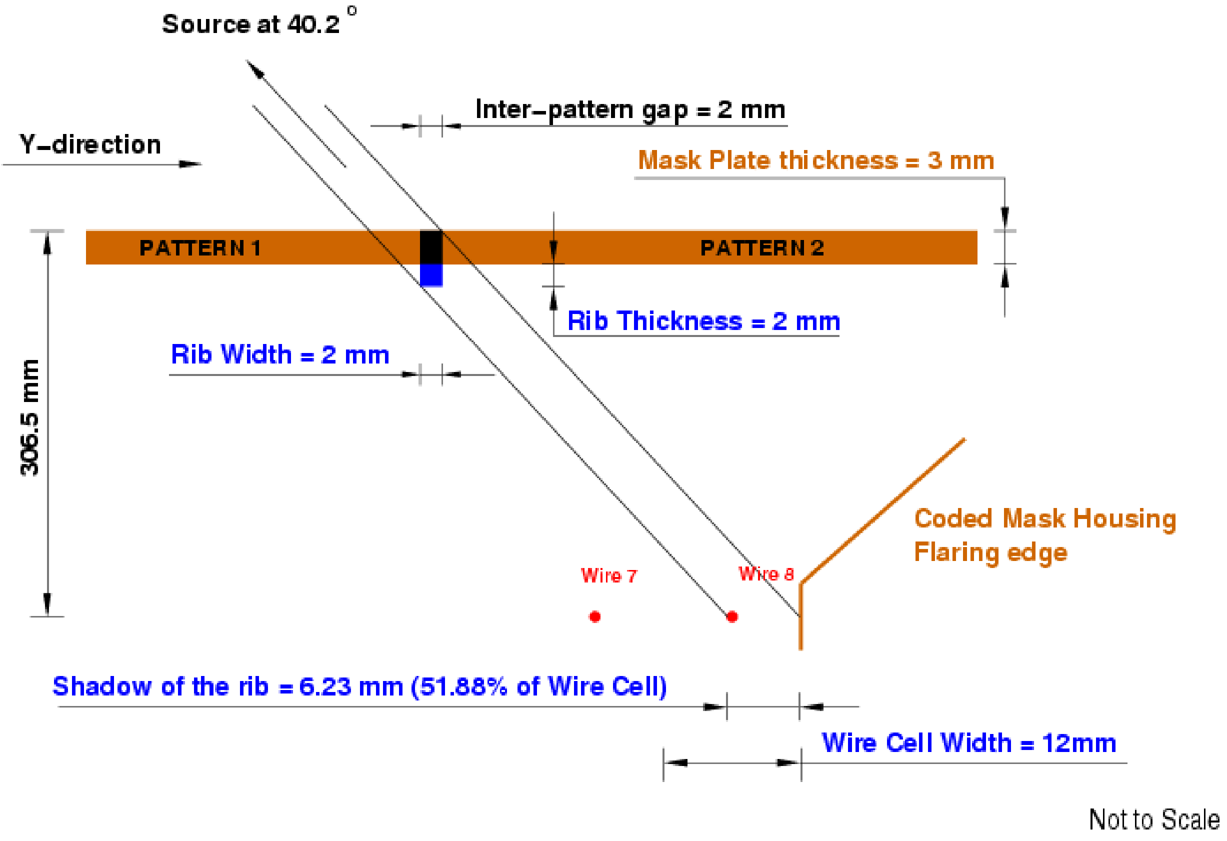

X–FOV–Edge (11.08°)
X–direction
60 mm
Outer Rib Width = 2 mm
5 mm
Outer Rib Height = 2 mm
Mask Coding
Coded Mask Housing
306.5 mm
Detector Wires
60 mm
Not to Scale


Y–FOV–Edge (49.98°)
Outer Rib Width = 2 mm
Outer Rib Height = 2 mm
Y–direction
634 mm
Six Mask Patterns
5 mm
306.5 mm
Coded Mask Housing
Detector Plane
96 mm
Not to scale

As is evident for both X and Y directions, for all possible incidences, outer ribs do not appear in the respective fields of view. Even if there is an illumination on the outer ribs, their shadows will fall on the outer side of the coded mask housing.

Inter-pattern ribs

The effect due to the inter-pattern ribs is shown in the following figure. For a given incidence, the shadow of only one inter-pattern rib can fall on the detector plane. For plotting the figure, the rib is assumed to be of width 2 mm and thickness 2 mm and the mask plate thickness is assumed to be 3 mm.

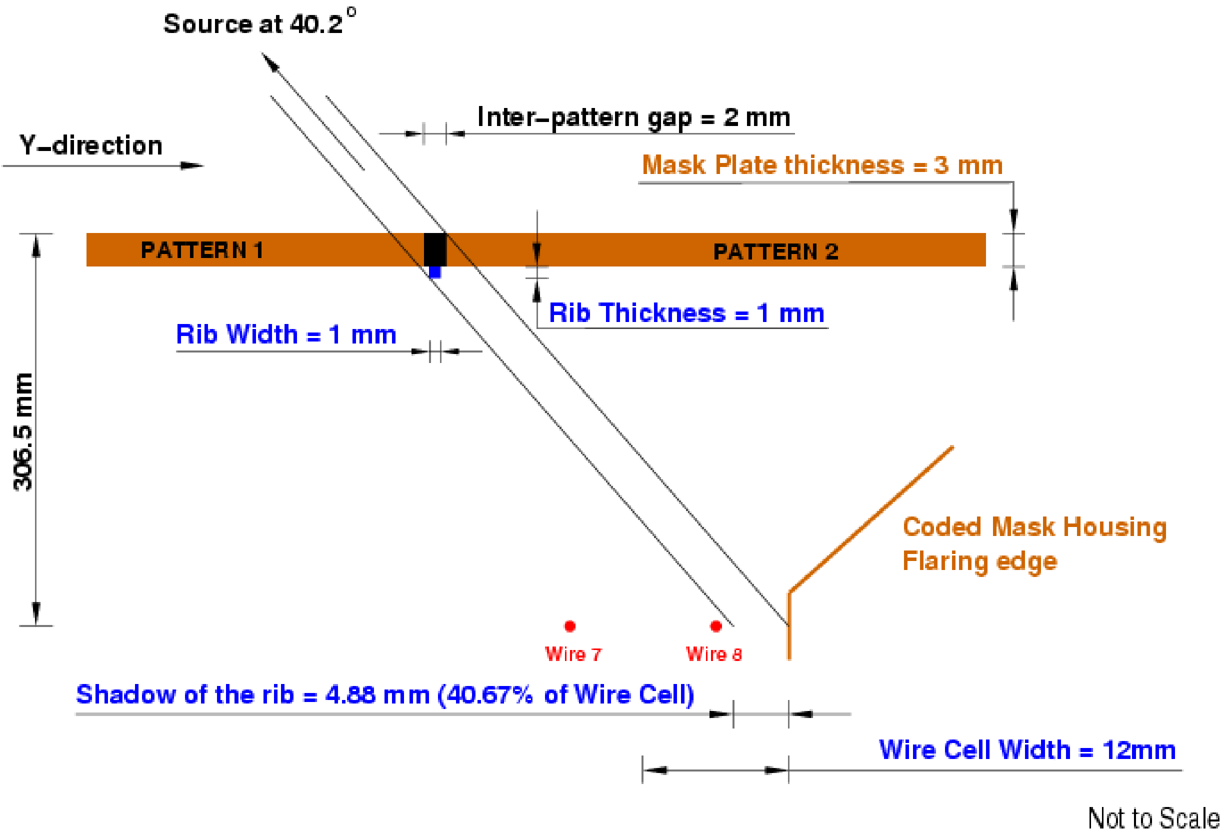

Source at 40.2 °
Inter-pattern gap = 2 mm
Y-direction
Mask Plate thickness = 3 mm
PATTERN 1
PATTERN 2
306.5 mm
Rib Thickness = 2 mm
Rib Width = 2 mm
Coded Mask Housing
Flaring edge
Wire 7
Wire 8
Shadow of the rib = 6.23 mm (51.88% of Wire Cell)
Wire Cell Width = 12mm
Not to Scale

As shown in the figure, the shadow cast by the inter-pattern rib for a source at 40.2° incidence is 6.23 mm in wire-cell-8. This corresponds to a loss of 51.88% of the width of wire-cell-8; rest of the wire-cell-8 and all other wire-cells will be illuminated with the shadow of mask pattern 1. For any other relevant angle of incidence, one of the eight wires only will be affected by the shadow of one of the inter-pattern ribs (but the loss will be less than 51.88%).

The following table summarizes the results for different combinations of inter-pattern rib thicknesses and mask-plate-widths. The table entries are the maximum possible lengths of the shadow cast by the inter-mask-pattern rib followed by the percentage of the wire cell width lost because of the shadow. The incidence angle for which the corresponding worst-case values have been obtained is 40.2°. For the calculations, an inter-mask-pattern gap of 2 mm has been assumed.

		Inter-Mask-Pattern rib		
		Thickness = 0 mm	Thickness = 1 mm Width = 1 mm	Thickness = 2 mm Width = 2 mm
Mask Plate Thickness	3 mm	4.54 mm (37.79%)	4.88 mm (40.67%)	6.23 mm (51.88%)
	1.5 mm	3.27 mm (27.23%)	3.61 mm (30.10%)	4.96 mm (41.31%)

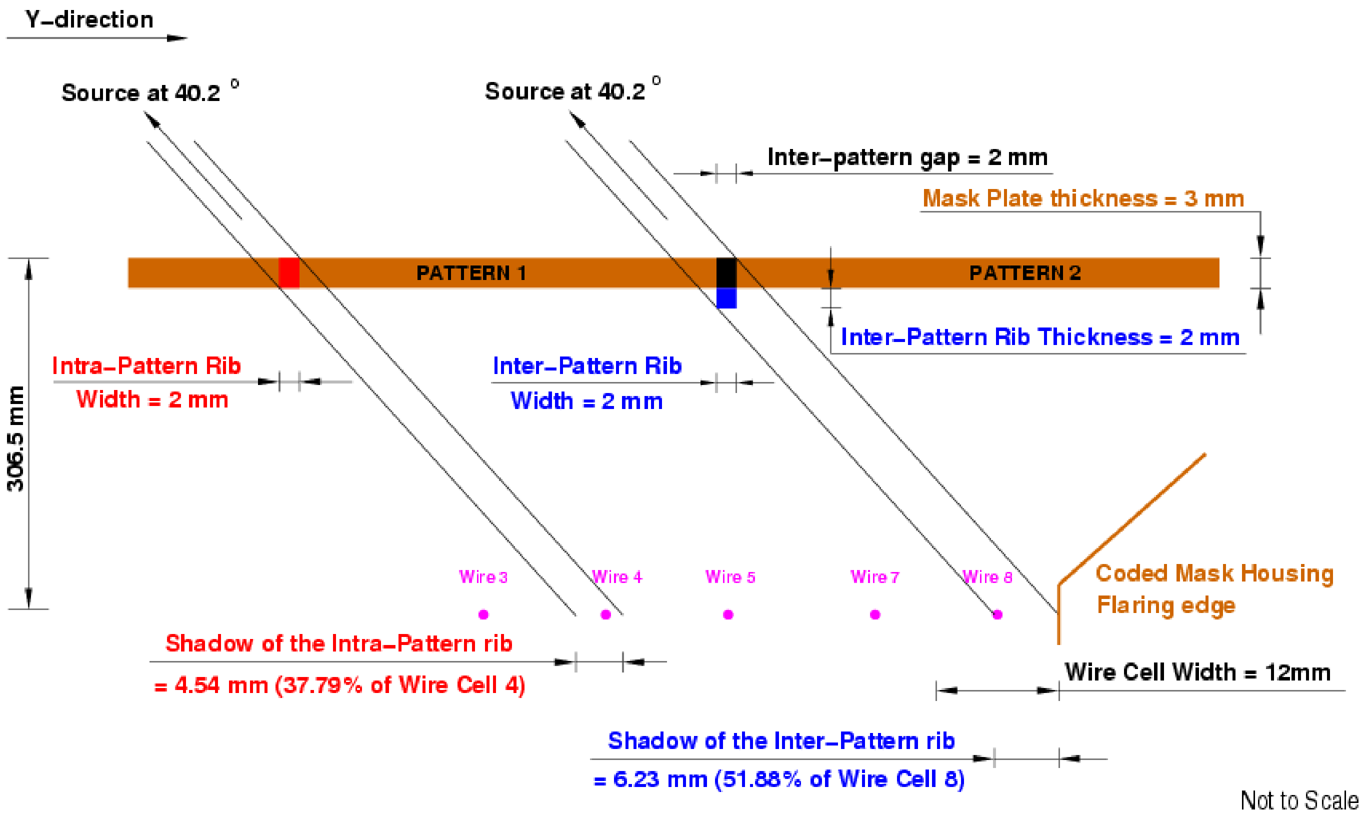
For the case: inter-pattern-rib of width 1 mm and thickness 1 mm (centered over the inter-pattern gap of 2 mm), the rib will be shadowed by the inter-pattern gap for all incidences in the range: -26.56° ≤ 0° ≤ 26.56° and hence the loss in the wire-cell-width will be less for these incidences (even otherwise less than that for 2mm × 2mm inter-pattern-rib for other incidences). The following figure illustrates this case for an incidence of 40.2° (for which the maximum length shadow of 4.88mm is cast on the detector plane).


Source at 40.2°
Inter–pattern gap = 2 mm
Y–direction
Mask Plate thickness = 3 mm
PATTERN 1
PATTERN 2
Rib Thickness = 1 mm
Rib Width = 1 mm
306.5 mm
Coded Mask Housing
Flaring edge
Wire 7
Wire 8
Shadow of the rib = 4.88 mm (40.67% of Wire Cell)
Wire Cell Width = 12mm
Not to Scale

Intra-Pattern Rib

The figure below shows the effect due to Intra-Pattern Rib. Excepting for angles across the mask-coding (Y) direction, for which the entire or part of the detector plane is illuminated with the shadow of a single mask pattern, for all other incidences, two wire-cells will be affected, one with the shadow due to inter-pattern rib (plus inter-pattern gap) and the other with the shadow due to the intra-pattern rib. For a given incidence, the shadow of one intra-pattern rib only can fall on the detector plane; it will be either one intra-pattern's shadow or shadows of adjacent intra-pattern and inter-pattern ribs falling simultaneously on the detector plane, the worst case scenarios of both of which are illustrated below.

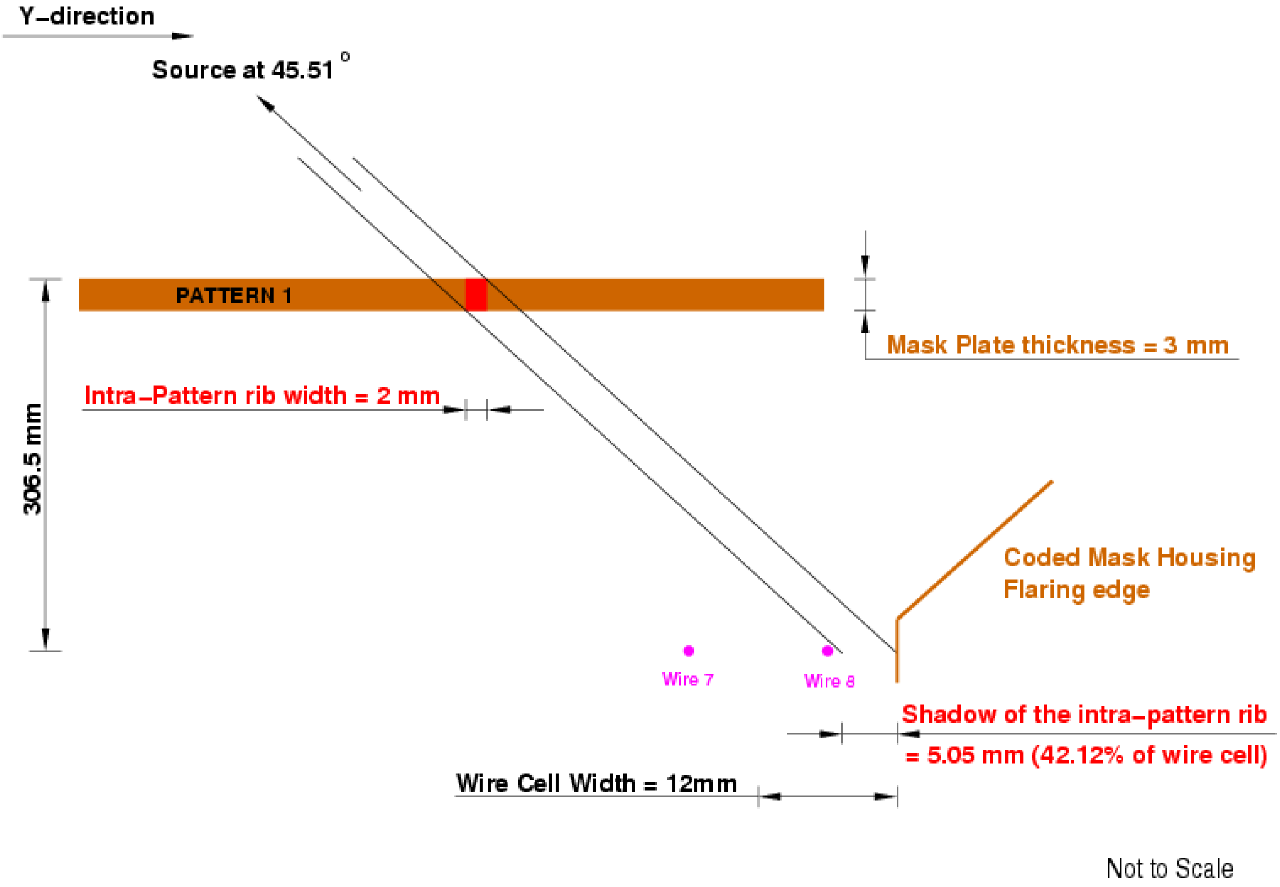
The intra-pattern ribs are assumed to be confined to within the mask plane (like the inter-pattern gaps). In the figure below, an intra-pattern rib of width 2 mm and thickness 3 mm (same as that for the mask-plate) are assumed.


Y–direction
Source at 40.2 °
Source at 40.2 °
Inter–pattern gap = 2 mm
Mask Plate thickness = 3 mm
PATTERN 1
PATTERN 2
Inter–Pattern Rib Thickness = 2 mm
306.5 mm
Intra–Pattern Rib
Width = 2 mm
Inter–Pattern Rib
Width = 2 mm
Wire 3
Wire 4
Wire 5
Wire 7
Wire 8
Coded Mask Housing
Flaring edge
Shadow of the Intra–Pattern rib
= 4.54 mm (37.79% of Wire Cell 4)
Wire Cell Width = 12mm
Shadow of the Inter–Pattern rib
= 6.23 mm (51.88% of Wire Cell 8)
Not to Scale

The figure illustrates the worst case possible for an incidence angle of 40.2° (with the assumed dimensions). More than 51% of wire-cell-8 is being shadowed because of inter-pattern-gap and inter-pattern-rib. The rest of wire-cell-8 and all other wire-cells will be illuminated with the shadow of mask-pattern-1 but 37.79% of wire-cell-4 will be shadowed by the intra-pattern-rib in mask-pattern-1.

The following figure shows the case when the entire detector plane is illuminated with the shadow of a single mask pattern. The maximum length of shadow of the intra-pattern-rib is possible for an incidence angle of 45.51°.

Again, the intra-pattern rib is assumed to be of thickness 3 mm and width 2 mm. As shown in the figure, 42.12% of the wire-cell-8 is shadowed by the intra-pattern-rib. The rest of the wire-cell-8, wire-cell-7, wire-cell-6, wire-cell-5 and 67.12% of wire-cell-4 will be illuminated with the shadow of mask-pattern-1.

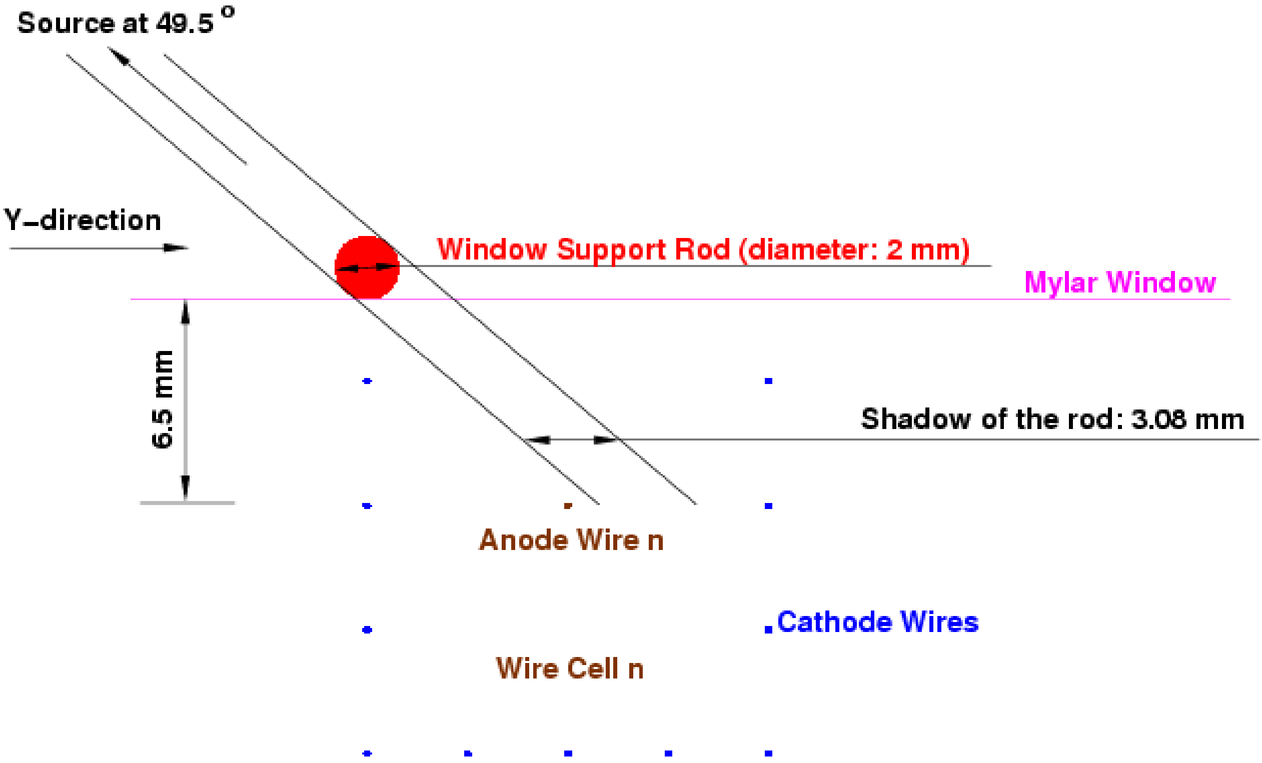

Y-direction
Source at 45.51 °
PATTERN 1
Mask Plate thickness = 3 mm
Intra-Pattern rib width = 2 mm
306.5 mm
Coded Mask Housing
Flaring edge
Wire 7
Wire 8
Shadow of the intra-pattern rib
= 5.05 mm (42.12% of wire cell)
Wire Cell Width = 12mm
Not to Scale

In the table below, the maximum length shadows for different combinations of the widths of the intra-pattern rib and the thicknesses of the mask plate are shown. The entries of the table are the shadow lengths followed by the percentage loss in the width of wire-cell-8. The term θ_i in the table is the incidence angle for which the maximum possible shadow is calculated for the corresponding cases.

		Intra-Mask-Pattern rib	
		Width = 2 mm θ_i = 45.51°	Width = 1 mm θ_i = 45.56°
Mask Plate Thickness	3 mm	5.05 mm (42.12%)	4.06 mm (33.82%)
	1.5 mm	3.53 mm (29.39%)	2.53 mm (21.08%)

Window Support Structure

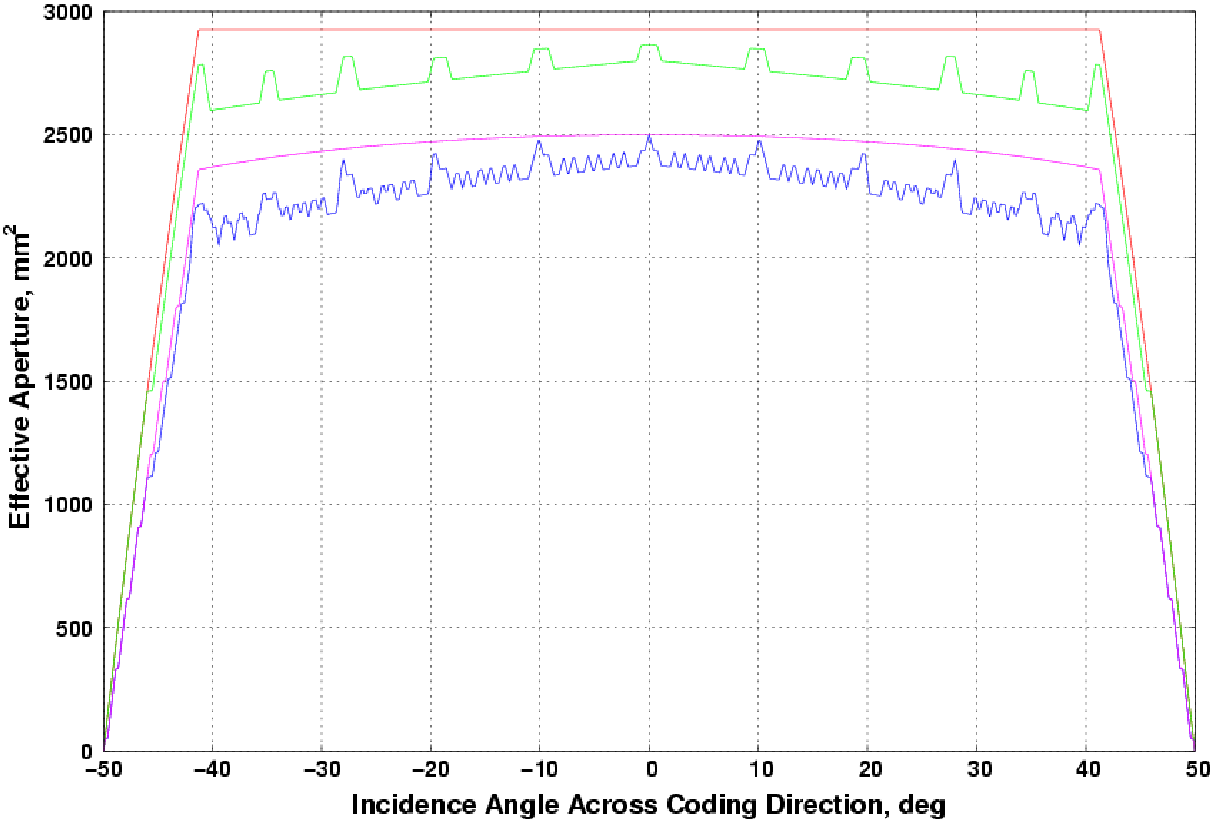
The effect of the **Window Support Rod** of diameter 2 mm is shown below:


Source at 49.5 °
Y-direction
Window Support Rod (diameter: 2 mm)
Mylar Window
6.5 mm
Shadow of the rod: 3.08 mm
Anode Wire n
Cathode Wires
Wire Cell n

This is also for the worst case possible, with a source at ~ 49.5°. The window support rod (of diameter 2 mm) casts a shadow of 3.08 mm. For this incidence, ~4.75 mm of the wire-cell-8 will be illuminated with the shadow of mask-pattern-1 and the shadow of 3.08 mm implies a loss of 64.72% of this effective width. The minimum loss of 14.58% $\left(\frac{2\times7}{96}\right)$ is when the source is at the normal incidence.

Collimator Response across the mask coding direction

The following figure shows the plot of effective aperture as a function of the incidence angle across the mask coding direction. The red curve is for the ideal case for a mask plate of 0 mm thickness with no ribs and without any window support structure. The blue curve is obtained when the mask plate is 3 mm thick, with an inter-pattern-gap of 2 mm, inter-pattern-rib of width 2 mm & thickness 2 mm (centered over the inter-pattern gap), intra-pattern-rib of width 2 mm and the window support structure of rods of diameter 2 mm. The green curve is obtained for the mask with ribs of dimensions mentioned above and without any window support structure. The purple curve is obtained for a mask plate of thickness 3 mm without any ribs and with the window support rods of diameter 2 mm.



For any given incidence angle, the shadow of either one intra-pattern rib or one inter-pattern-rib (plus inter-pattern-gap), or the shadows of adjacent intra-pattern rib and inter-pattern rib (plus inter-pattern gap) simultaneously will be falling on the detector. The response (green curve) goes down when shadows of both the intra-pattern rib and the inter-pattern rib (plus inter-pattern gap) are falling on the detector and peaks when the shadow of only one of them is falling on the detector. There are eleven peaks in the green curve because of five inter-pattern ribs (plus inter-pattern gaps) and six intra-pattern ribs. The response goes down further in the presence of the window support rods (as shown in the blue curve).