SDN 2002 Thermal Shift of the Optical Path into the Cryostat

1.0 Introduction

Due to thermal contraction there will be a three axis translation of the cryostat optical path with respect to the cryostat mount upon cooling. Since the cryostat will be built and aligned warm it must be built with an offsetting "error" so that the instrument will come into alignment when it is cooled. This offset will happen at the first cold baffle after the window. The window is on the vacuum jacket and is warm and will stay centered on the beam. The cold structure inside must be offset in three directions. When looking into the window with the cryostat warm the first baffle will be decentered with respect to the window. Once cooled the first baffle will be centered. This decentering covers two axis. The third is focus. There is also a focus shift upon cooling.

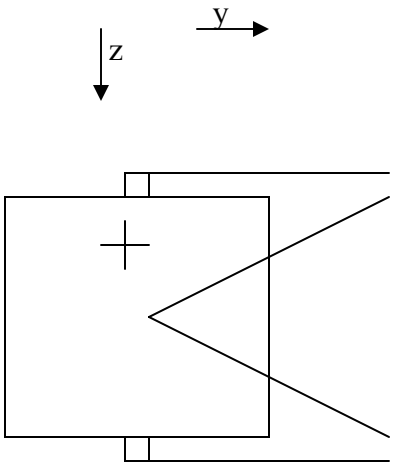
This memo will specify the shift required in the warm design to achieve alignment when the instrument is cold.

2.0 Coordinates

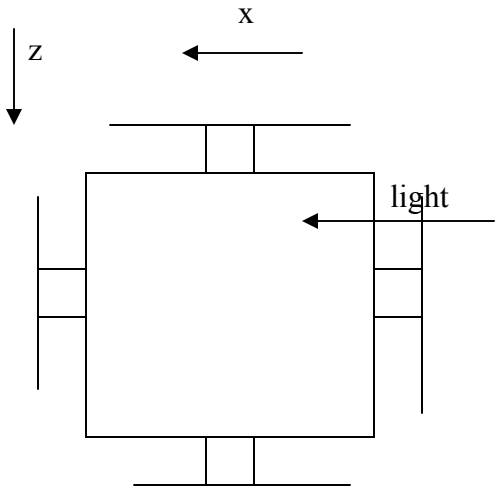
The coordinate system used here is that of the Ideas model. There is no particular significance of the x, y and z labels for the cryostat since the cryostat is folded orthogonal to the original z optical axis. While this coordinate system is a little confusing, the purpose of this memo is to instruct the mechanical designer as to the required offset and therefore the designer's native coordinate system seemed best.

The x axis is parallel to the cryostat incoming light path. The x value gets more positive going into the cryostat. This would be thought of as the focus direction.

The y axis and the z axis are the two translation coordinates in the plane of the window and parallel to the sides of the cryostat. The arrow head shows more positive direction.



Looking into window



looking down on trusses, vertex toward viewer

3.0 Fixed Point

Then using flex tabs, shear webs or in this case v-trusses there is a concept called the fixed point. If you were to draw a line, normal to the plane of the truss, through the bolt at the vertex of each truss and if the trusses are symmetrically placed then the four lines will intersect at a point called the fixed point. For two of the three dimensions all points on a cold structure will shrink towards the fixed point. In other words that point will stay were it is during cooldown(in two dimensions) and every other point will move towards it. The two axis over which the fixed point is fixed are the two axis that define the plane that would contain the four truss vertex points. The third axis is the one parallel to the trusses. Since the trusses shrink when cooled the fixed point is pulled toward the truss anchor point when cooled. Sometimes the optical path can be put on the fixed point so that there is no shift during cooldown. Sometimes small focus shifts are no trouble. IN NICI the optical path could not be placed intersecting the fixed point and the focus accuracy requirement is very tight so we must accurately calculate these shifts and correct for them.

4.0 V-truss shrinkage

One important parameter for the up coming calculations is the amount that the v-trusses shrink when cooled. This is not a simple calculation since the G-10 truss is not one temperature but goes from 300K at one end to 70 K at the other. Additionally the trusses have stainless steel ends(303) that have a different expansion coefficient. The approach used here is to brake the truss up into 10 slices and assign a temperature for each and then use the expansion coefficient for that temperature and then sum to get the total contraction. The temperature for each slice of G-10 is computed based on conductivity falling off as the G-10 gets colder so the temperature drop per slice is greater at the colder temperatures. The table below shows the result of this approach.

Slice	**Length**	**Temperature**	**Contraction %**	**Contraction**
Stainless foot	1.84419	300	0	0
Fiberglass section 1	1.09096	270.83	.030	.000327
Fiberglass section 1	1.09096	254.23	.047	.000513
Fiberglass section 1	1.09096	234.78	.067	.000731
Fiberglass section 1	1.09096	211.73	.091	.000993
Fiberglass section 1	1.09096	185.80	.118	.00129
Fiberglass section 1	1.09096	157.02	.147	.00160
Fiberglass section 1	1.09096	124.67	.181	.00197
Fiberglass section 1	1.09096	88.72	.218	.00238
Stainless apex	4.000	70	0.32	.0128
			Total Contraction	0.022604 inches

For a check, multiplying the length of the fiberglass(8.728 inches) by ½ of the contraction value for 77 K(1/2 of .23%) and then add the contraction for the 4 inches of

stainless apex(4.00x0.0032) gives 0.022837 inches. Maybe the long method is not needed.

Contraction of the V-truss is 0.022604 inches in the y direction.

5.0 Coordinates of the fixed point and the focal plane

In the Ideas model the coordinates are in the table below:

	X	Y	Z
Fixed Point	21.58831	-4.07196	36.29437
Focal plane above window	17.77399	-7.181764	28.88037
Difference	3.81432	3.10980	7.41400

6.0 Beam movement in the Z axis direction

In the Z direction all that is involved is the shrinkage of the aluminum cold structure of the point in the center of the focal plane toward the fixed point. This is simply 7.41400 times the coefficient for Aluminum at 70 K, which is 0.395%.

The movement in the Z direction due to cooling is 0.0293 inches. Movement is in the plus Z direction toward the fixed point.

7.0 Beam movement in the Y axis direction

Since the center of the focal plane is on the opposite side of the fixed point than the trusses the total shrinkage is the shrinkage of the trusses plus the shrinkage of the cold structure between the fixed point and the focal plane. That is:

0.022604 inches + 3.10980 x 0.395%

The movement in the Y direction due to cooling is 0.0349 inches. Movement is in the plus Y direction towards the feet of the trusses.

8.0 Beam Movement in the X direction

The focal length of the parabola will reduce by 0.395% since it is made out of aluminum. This will pull the focus back towards the cryostat. At the same time however the parabola is displaced from the fixed point so it will move toward the fixed point. The result is that most of the image plane movement in the X direction which is the focus direction is canceled. The portion that is not canceled is the portion of the focal length of that mirror that is on the other side of the fixed point. This is the difference between the fixed point and the focal plane in the X direction which is 3.81432 inches. This portion will be reduced by the coefficient for aluminum(0.395%).

The Movement in the X direction(focus) due to cooling is .0151 inches. The movement is in the plus X direction moving the image plane toward the window or into the dewar**.**