LCLS Engineering Specification Document # 1.5-133	X-Ray Transport and Diagnostics	Revision 0

Collimators in the XTOD Offset Mirror System

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Brief Summary: This document provides engineering specifications for Collimators in the XTOD Offset Mirror System (OMS). It describes the collimator system concept previously approved, together with the additional specifications and requirements that stem from it.

Change History Log

Rev Number	Revision Date	Sections Affected	Description of Change
000	2008/12/16	All	Initial Version

1. **Introduction:**
   A semi-formal System Concept Review (SCR) was completed for Collimators in the XTOD Offset Mirror System (OMS) on April 17, 2007. This document describes that system concept, together with the additional specifications and requirements that stem from it.
2. **Collimator Fundamental Requirements:**
   Fundamental physics requirements for the collimators are detailed in Sections 1 and 2 of LCLS PRD 1.5-017, *Physics Requirements for Collimators in the XTOD X-Ray Offset Mirror System*, and will not be repeated here.

3. **Additional Specifications and Requirements:**
   3.1. Primary Collimator Materials: The primary collimator shielding material will be tungsten heavy alloy (WHA). The upstream face of the collimator WHA cylinder will be protected from FEL damage using boron carbide (B_4C). Specifications for the materials to be used are given in Table 1 below.

Table 1: Primary Collimator Materials

WHA		
Basic Composition	95W, 3.5Ni, 1.5Fe (wt%)	
Density	> 18 g/cm^3	
Designations and Suppliers	HD 18DV	Mi Tech Metals, Indianapolis, IN 46216
	Kulite Alloy K 1810	H. C. Starck, West Chester, OH 45069
Notes:	Special UHV grade developed for the Advanced Photon Source at Argonne National Lab. Contains only virgin tungsten powder metal, no recycled material, to minimize impurities. Sintering program specially tailored for zero porosity through the entire compact thickness.	
B_4C		
Plate Thickness	10 mm	
Composition	Boron + Carbon > 99% wt	
Hot-Pressed Density	> 95% theoretical	
Theoretical Density	2.52 g/cm^3	
Supplier	Ceradyne, Inc., Boron Products LLC, Quapaw, OK 74363	
Notes:	High-purity, hot-pressed, natural isotopic composition.	

   3.2. Minimum Collimator Dimensions: The radiation length and Molière length of the WHA, specified in Table 1 above, was calculated using the data and methods detailed in Appendix 1 of PRD 1.5-017. The results are listed in Table 2 below:

Table 2: Radiation and Molière Lengths for the WHA

Radiation Length	3.85 mm
Molière Length	9.83 mm

Sections 1.1.2 and 1.1.3 of PRD 1.5-017 specify that the longitudinal dimension of the collimator shall be at least 20 Radiation Lengths in the component material, while the radial dimension of the collimator shall be at least 6 Molière Lengths. This results in the minimum collimator dimensions illustrated in Figure 1 below. Note that the radial dimension is specified from the outer edge of the central aperture, not the aperture center.

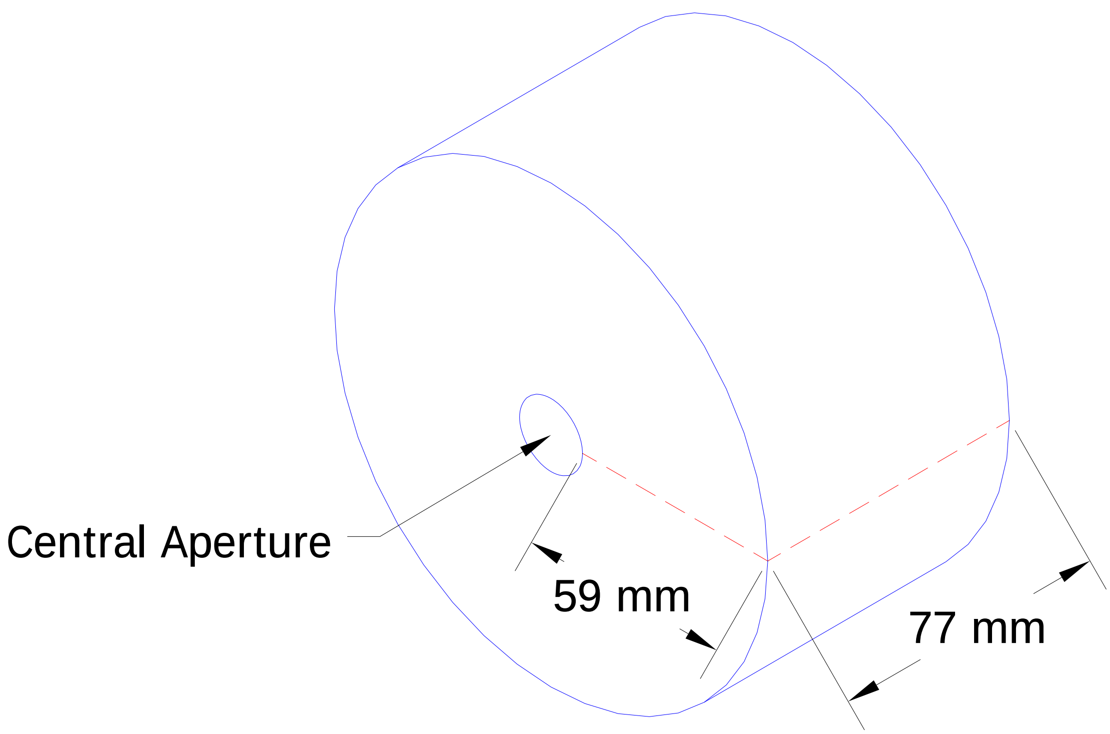

Figure 1: Minimum Collimator Dimensions using WHA from Table 1.

3.3. Locations of Collimators: The XTOD collimator locations are schematically illustrated in Figure 2 below. Six are located in the Front End Enclosure (FEE), four in Near Experimental Hall Hutch 1 (NEH 1), and one just downstream of NEH 3.

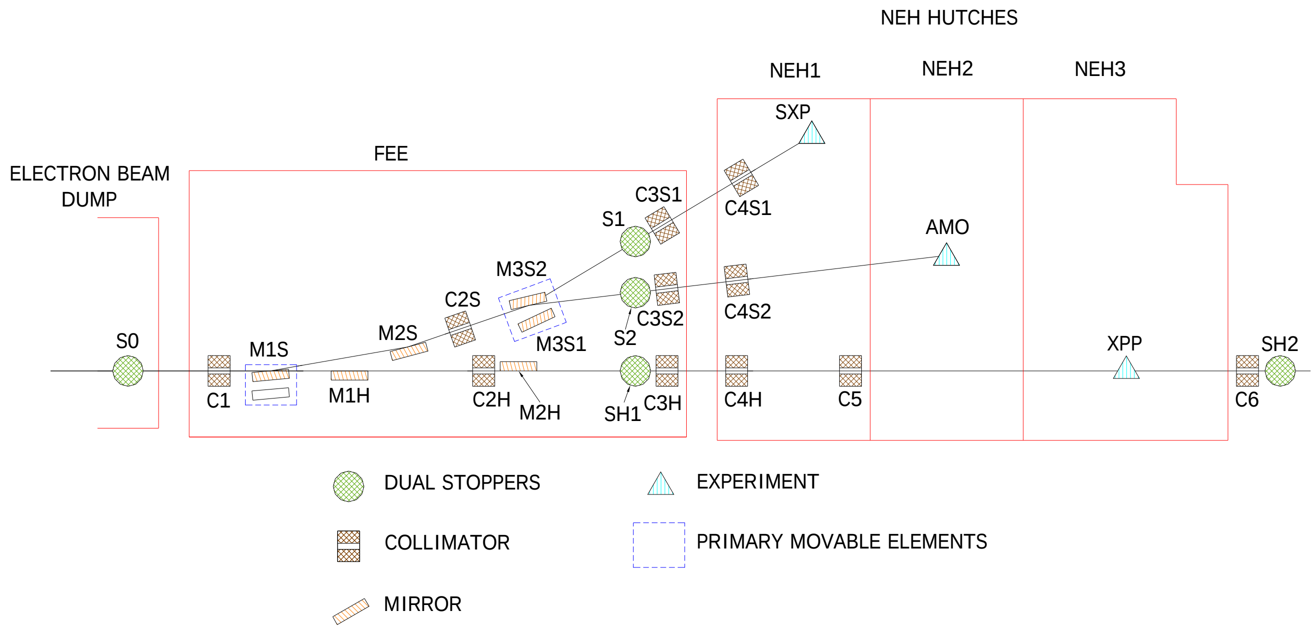

Figure 2: Schematic illustration of primary OMS components, including the collimators.

3.4. Dimensions of C1: As suggested in Section 2.1 of PRD 1.5-017, the outer, radial dimension of C1, the initial collimator, may have to be increased above the minimum dimensions specified in Section 3.2 above. Acting upon guidance from SLAC Radiation Physics, the following situation was analyzed to obtain the minimum required outer, radial dimension of C1. The results are illustrated in Figure 3.

3.4.1. The primary vertical-bend electromagnets in the Electron Beam Dump are shut off.

3.4.2. The safety dump permanent magnets in the Electron Beam Dump are all de-magnetized.

3.4.3. The remaining quadrupole and steering magnets in the beam dump transport are able to direct the electron beam through the worst-case edges of PCPM1, PCPM2, and C0.

3.4.4. The electron beam enters the FEE.

3.4.5. All extreme rays for this electron beam must terminate on C1.

As can be seen in the "beam's eye" view portion of Figure 3, the worst-case projection of the elliptical aperture PCPM1 through rectangular aperture C0 extends to a diameter of ~125 mm at C1. Therefore, the overall radial dimension of C1 must exceed this by some comfortable margin.

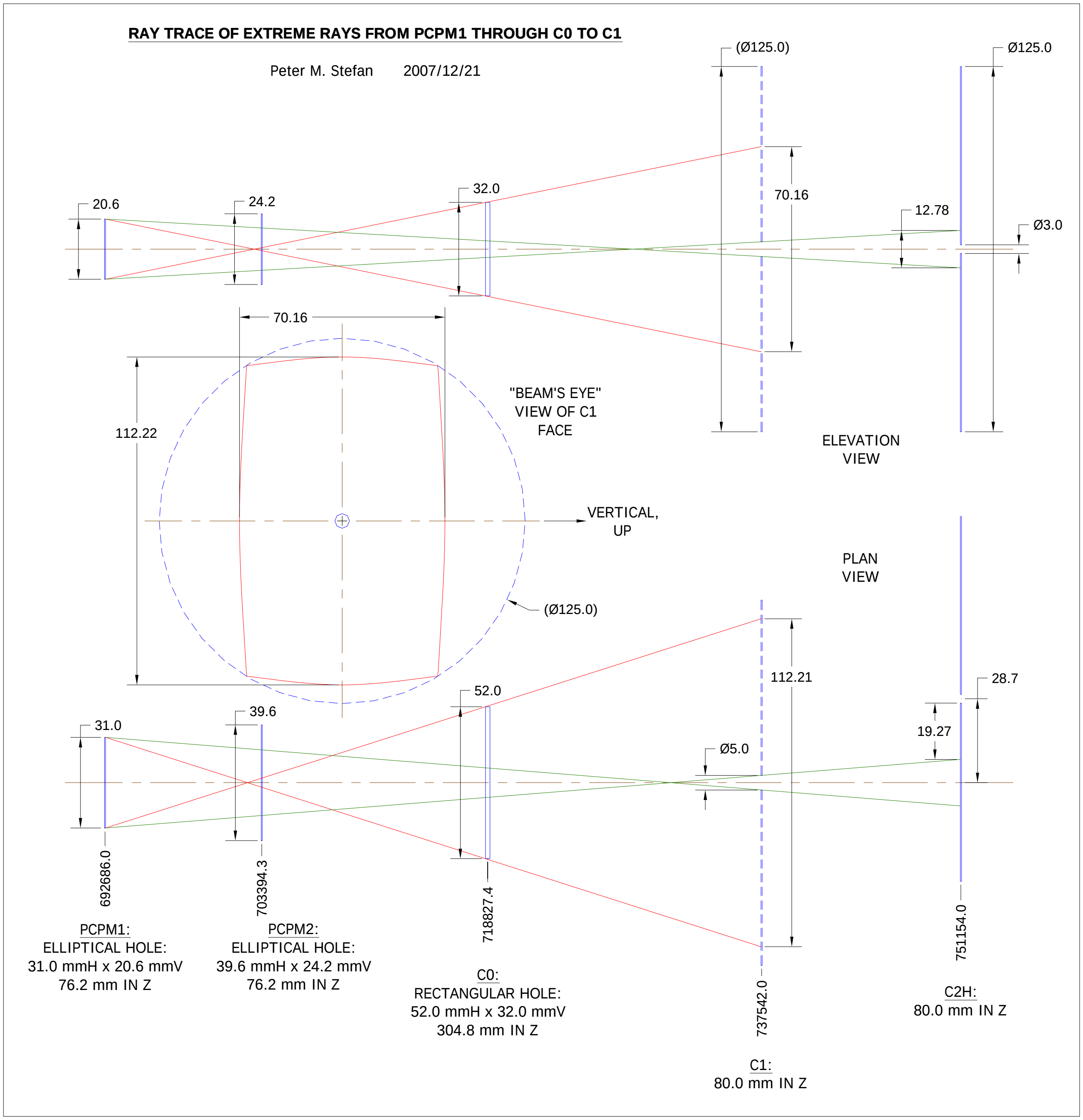

Figure 3: Ray trace utilized to determine the minimum radial extent of collimator C1.

3.5. Physical Dimensions of Collimators: The physical dimensions adopted for the WHA shielding cylinders in all XTOD collimators are summarized using Table 3.

Table 3: Collimator WHA shielding cylinder dimensions

Collimator	Aperture Diameter (mm)	Outside Diameter (mm)	Z-Length (mm)
C1	5	174.2	
C2S, C3S1, C3S2, C4S1, C4S2		124.8	80
C2H, C3H, C4H, C5, C6	3		

3.6. <u>SLAC Radiation Physics Mandates:</u>

3.6.1. Polyethylene Shielding: Designs must be devised to accommodate 4 inch thick polyethylene shielding around collimators C4H and C5, to attenuate generated photo-neutrons.

3.6.2. Protection Ion Chambers (PIC's): Pairs of PIC's must be located immediately downstream of C1 and C2H. They should be positioned as schematically indicated in Figure 4 below.

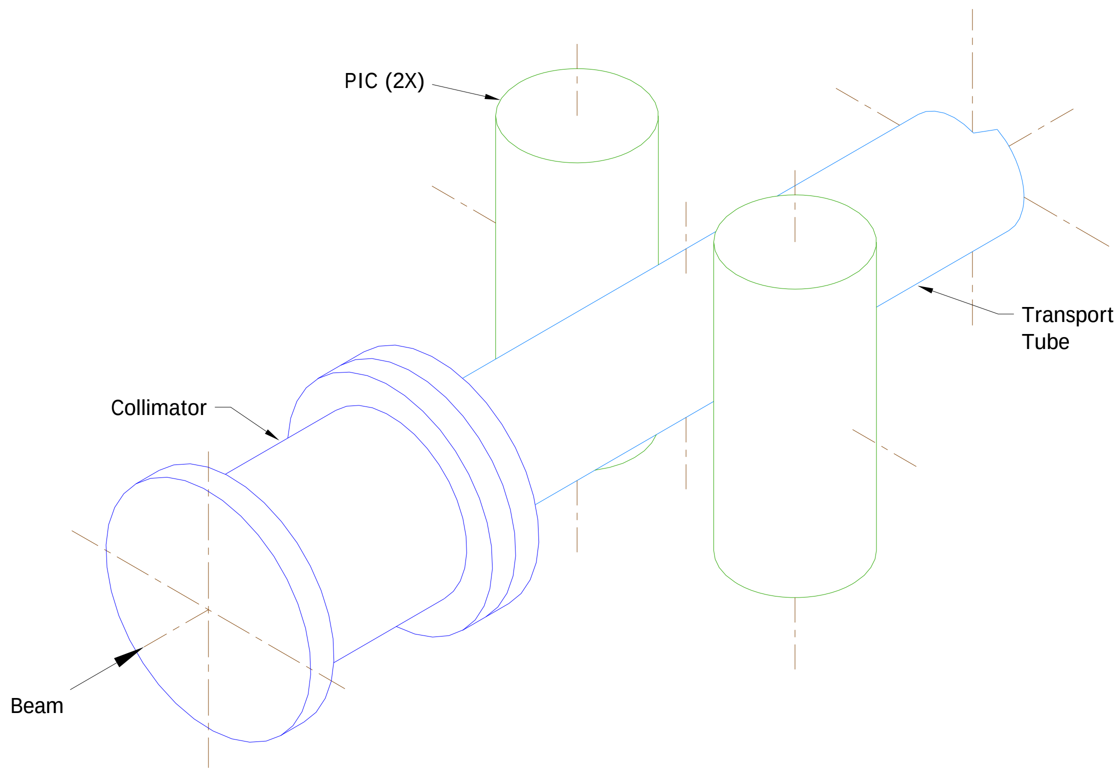

Figure 4: Positioning of PIC's downstream of collimators.

3.6.2.1. Position immediately downstream of collimator, in order to receive the radiation shower generated by the collimator.

3.6.2.2. Pair of PIC's is equally spaced about beam centerline, as close to beam centerline as possible.

3.6.2.3. Mid-length of PIC's to be ~ located in horizontal plane containing the beam.

3.6.2.4. PIC dimensions can be obtained from SLAC drawings AD-900-681-00 and PF-900-681-01.

4. Collimator Basic System Concept:

The adopted system concept for the XTOD collimators is illustrated using Figure 5 and Figure 6. An overview of the collimator system concept is presented in Figure 5, while Figure 6 presents details.

4.1. In Figure 5, the vacuum housing, which contains both the B_4C and WHA shielding elements, is illustrated as Item 1.

4.2. The alignment mechanisms for the collimator are all located within the enclosure indicated as Item 2. This enclosure is split into two halves, along a plane perpendicular to the z-axis, at a point halfway along its z-length.

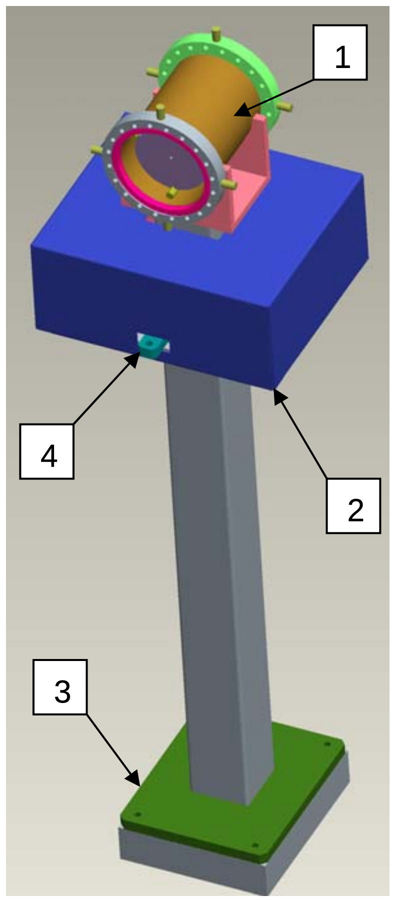

Figure 5: Overview of Collimator system concept.

4.3. The floor stand, Item 3, is bolted to the floor, with grout placed underneath. However, once the stand has been properly leveled, the exposed portions of the floor anchors will also be grouted-over, to prevent tampering/adjustment.

4.4. Item 4 is a "padlock station", located at the upstream end of the collimator assembly. A similar station is placed at the downstream end of the assembly.

They extend through the enclosure (Item 2). Even though the enclosure is attached to the collimator assembly using a series of tamper-resistant bolts, if all of these bolts were removed, the enclosure still cannot be removed, as long as padlocks are locked into the padlock stations.

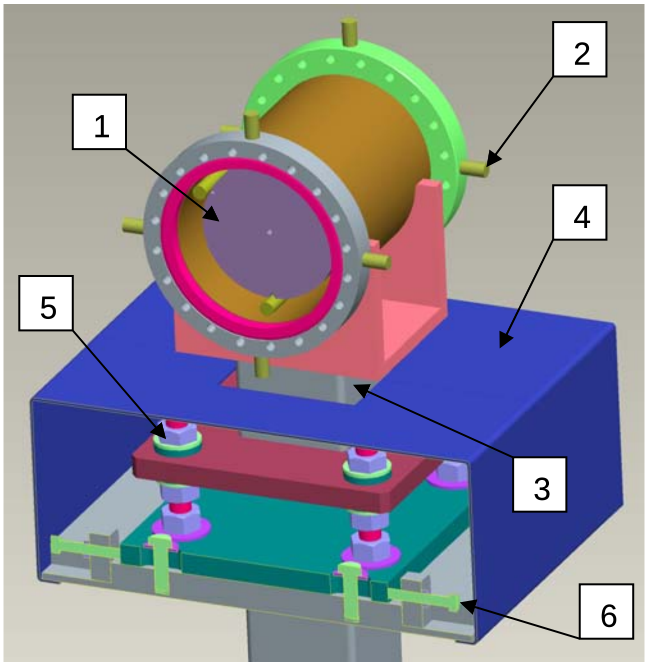

Figure 6: Collimator assembly details.

4.5. In Figure 6, Item 1 is the B_4C plate, mounted immediately upstream of the WHA alloy cylinder.

4.6. Item 2 indicates one of several permanent fixtures for holding survey/alignment tooling. Using these fixtures, the precise location of the collimator aperture can be determined without dismantling the vacuum system to see the aperture itself. Also note that these fixtures remain accessible even when the alignment controls are secured within the controls enclosure (Item 4 in Figure 6). Therefore, the location of the collimator aperture can be verified periodically, independent of whether adjustments are anticipated or not.

4.7. The collimator vacuum housing is supported using a welded cradle, column, and plate assembly, indicated as Item 3.

4.8. A collection of four threaded studs, equipped with double nuts and spherical washers sets, permits y-axis position adjustment of the collimator, in addition to pitch and roll angle adjustment. One of the stud assemblies is indicated as Item 5.

4.9. X-axis and yaw angle adjustment are provided using a collection of pusher screws, one of which is indicated as Item 6. Once these adjustments are made, additional screws are used to lock the adjustable assembly in place.

5. Remaining Work to Be Done:

5.1. Mechanical Analysis/Design: The following topics must be addressed through mechanical analysis and design:

5.1.1. Devise a reliable, low-stress mounting scheme for the B_4C plate to the WHA cylinder.

5.1.2. Customize the basic stand design, where necessary, to accommodate the realities at each of the 11 collimator mounting locations. For example, special stands will be needed for C3S1 and C3S2, because they are located very close to each other.

5.1.3. Perform the required earthquake safety mechanical analysis.