LCLS Engineering Specifications Document # 1.5-104	XTOD	Revision 0

LCLS XTOD FIXED MASK

Patrick Duffy Author (Fixed Mask)	Signature	10/30/06 Date
Kirby Fong Author (Simulations)	Signature	10/30/06 Date
Richard Bionta XTOD Manager	Signature	10/31/06 Date
Peter Stefan XTOD Physics Liaison	Signature	2006/11/2 Date
John Arthur Photon Systems Manager	Signature	11-3-06 Date
Darren Marsh Quality Assurance Manager	Signature	11/3/06 Date
John Galayda Project Director	Signature	11/3/06 Date

Summary: This initial Engineering Specifications Document (ESD) for the XTOD Fixed Mask System builds upon Physics Requirements Document (PRD) 1.5-007, *Physics Requirements for the XTOD X-Ray Slits and Fixed Mask System*, to add additional requirements and derived specifications. In addition, it documents supporting calculations utilized in generation of the PRD.

Change History Log

Rev Number	Revision Date	Sections Affected	Description of Change
000	10/30/06	All	Initial Version

Disclaimer

Auspices Statements

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.
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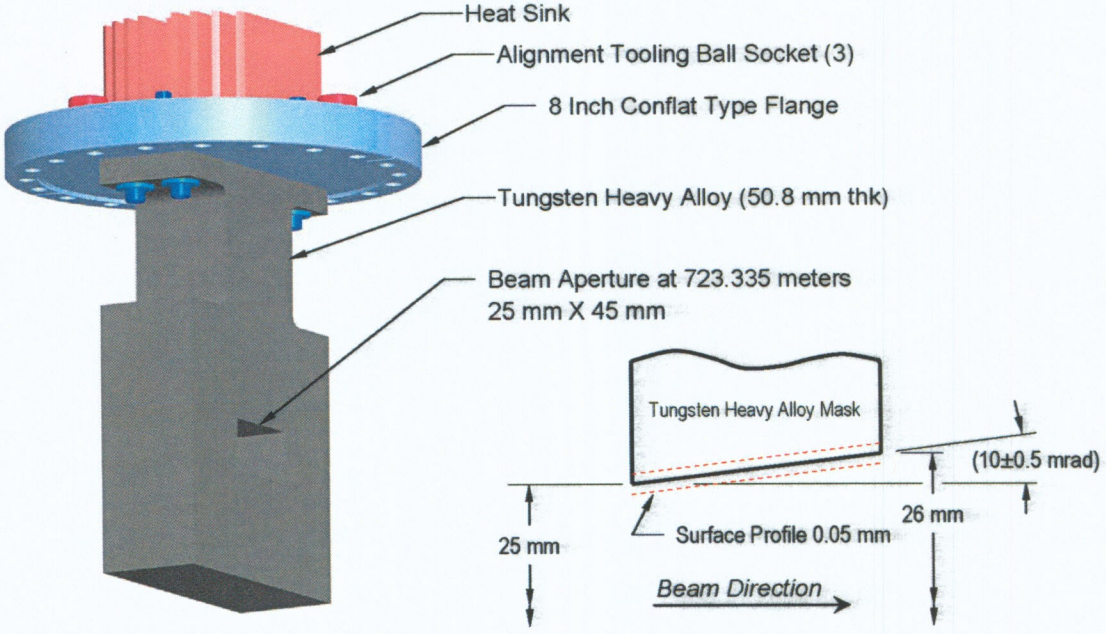
1. **Fundamental System Requirements:** PRD 1.5-007, *Physics Requirements for the XTOD X-Ray Slits and Fixed Mask System*, presents the fundamental requirements for the system. These requirements will not be reiterated here. The reader is referred to the released document.

2. **System Concept Description**
   - 2.1. The Fixed Mask consists of a block of specified-composition Tungsten Heavy Alloy (WHA) located at 723.335 meters (LCLS coordinates), and is upstream of the X-Ray Slit, primary wide-field-of-view systems, and diagnostics. The Fixed Mask will have a defined aperture, to limit radiation surrounding the FEL from entering the Front End Enclosure (FEE).
     - 2.1.1. The aperture will employ a negative rake angle on all four edges, to avoid specular reflection.
   - 2.2. The WHA block will be bolted to a vacuum flange, to facilitate alignment and heat removal.
     - 2.2.1. Three external alignment targets (alignment tooling ball sockets) will be mapped to the aperture to allow alignment when the system is under vacuum.
     - 2.2.2. A removable aluminum heat sink will be used to facilitate cooling of the Fixed Mask, through a combination of conduction and convection.
   - 2.3. The vacuum chamber design will permit overlap and extension of the shielding effect from the WHA block using an external lead shield.



3. **Additional Requirements and Derived Specifications**
   - 3.1. The design should allow replacement of the Fixed Mask, in case of damage or should changes to the aperture dimension be required.
   - 3.2. SLAC has recommended the following manufacturers of UHV-compatible WHA
     - 3.2.1. H.C. Starck – Kulite® K1810
     - 3.2.2. Mi-Tech Metals Inc. HD-18DV

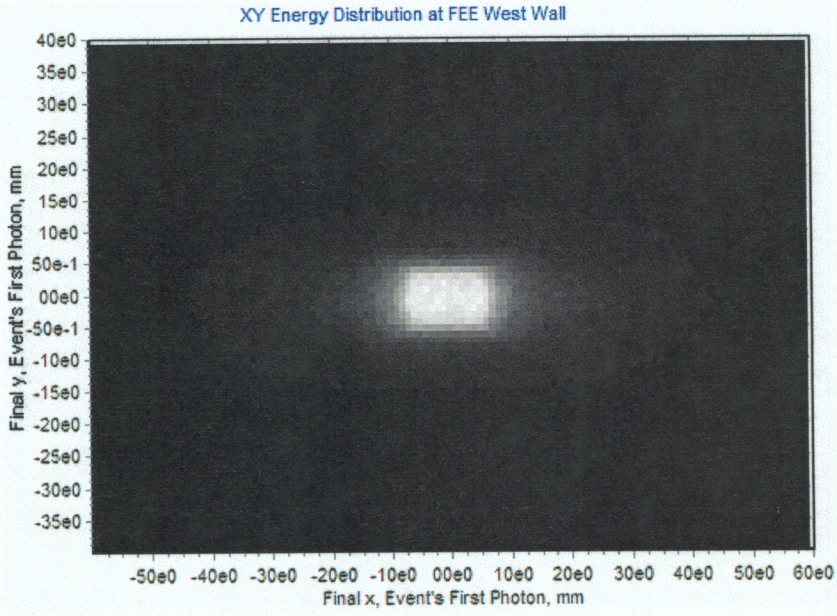
3.3. Vacuum System Requirements
  3.3.1. Pump down time of 8 hours or less.
  3.3.2. Operating Pressure: Among the various LCLS documents and requirements pertaining to the permissible vacuum pressure within XTOD subsystems, in compact, non-distributed systems such as the present one, the 10 year requirement for ion pump life is determining.
    3.3.2.1. A vacuum pressure of better than 4e-7 Torr shall be maintained at the ion pump input flange, to meet the required 10-year lifetime.
    3.3.2.2. To estimate the vacuum pressure at the ion pump input flange, the following gas load contributions shall be considered:
      3.3.2.2.1. Outgassing from the Fixed Mask System.
      3.3.2.2.2. Outgassing from the X-Ray Slit System.
      3.3.2.2.3. Gas loads from the Electron Beam Dump.
      3.3.2.2.4. Gas loads from the Attenuator/Gas Detector System.

3.4. The detailed geometry of the aperture, incorporating a negative rake angle of 10 ± 0.5 mrad, is illustrated in the figure above.

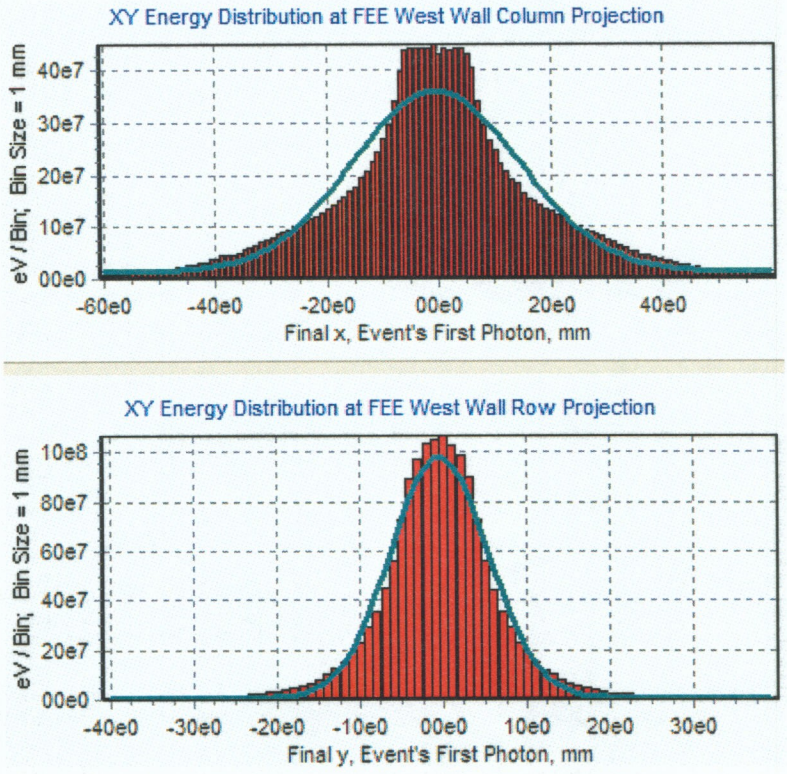
4. Documentation of Supporting Calculations: Evaluation of Fixed Mask Aperture Size

4.1. Alignment and commissioning procedures will require the use of spontaneous radiation. To verify that the selected aperture accommodates these requirements, we have performed Monte Carlo simulations to see the effect of the Fixed Mask on the beam. The model tracks the spontaneous photons from their birth in one of the undulator segments, through the undulator vacuum and diagnostics pipes, and through the Fixed Mask, while allowing for photoelectric absorption, Compton scattering, and reflection.

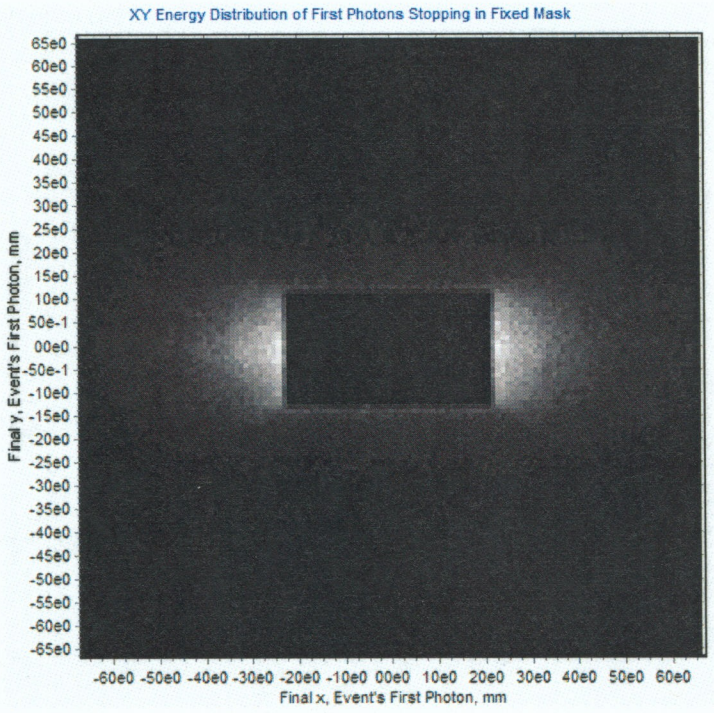
4.2. The expected spontaneous fluence at the entrance to the FEE is shown in the following plot. The simulation places no obstructions between the end of the undulator and the entrance to the FEE. The electron energy is 4.5 GeV, so this is the spontaneous radiation for the Soft X-Ray FEL setting. The gray level of a pixel is proportional to the sum of the energies of all photons falling into that pixel.

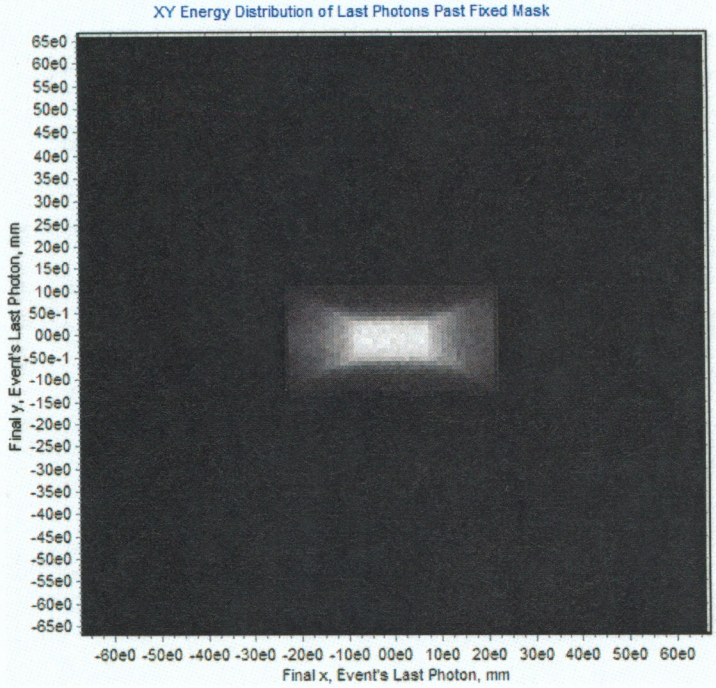


4.3. The next plots show projections onto the X and Y axes. The blue curves are Gaussian fits to the data. "Column projection" means projection of column data onto the X axis, and "row projection" means projection of row data onto the Y axis. The XY plane has been divided into millimeter square bins for accumulating the photon energies. The fluence scale on the left must be multiplied by 1.66×10^5 because the simulation was done with 10^7 photons and a full pulse is 1.66×10^{12} photons for a 0.79 nC electron bunch. In particular, the total energy arriving at the FEE west wall is approximately 0.41 millijoules.

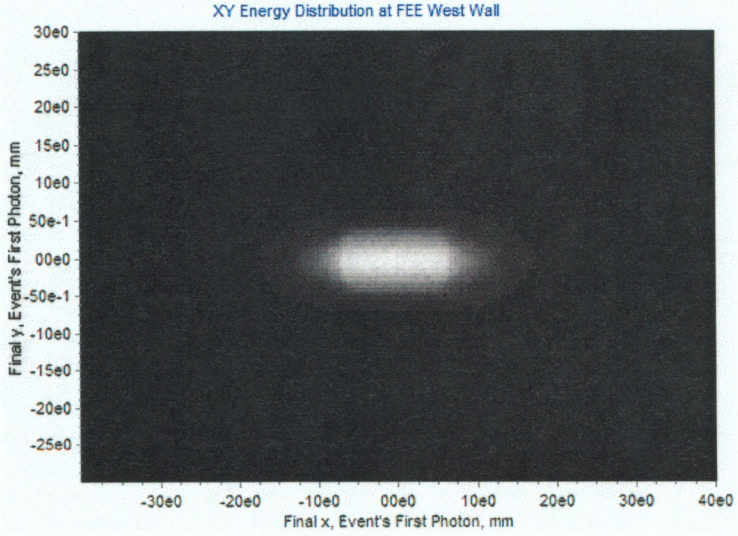


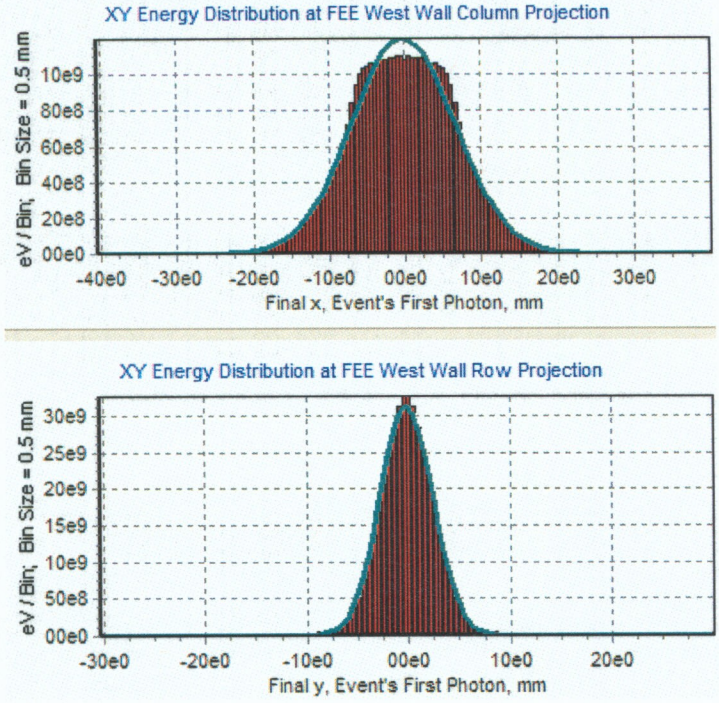
4.4. For the next step in the simulation, we insert the Fixed Mask. It is modeled as a WHA block, 133.4 mm square x 50 mm thick, centered 1.389 meters downstream from the FEE west wall. The aperture is modeled in eight slabs with increasingly larger apertures, to approximate a 25 x 45 mm entrance with a negative rake of 10 milliradians. It absorbs about 0.11 millijoules. In the second plot we see that the energy delivered through the aperture is about 0.30 millijoules.



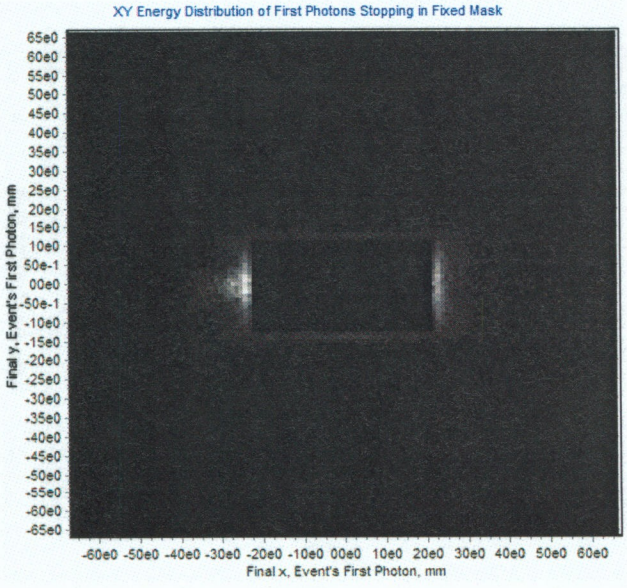


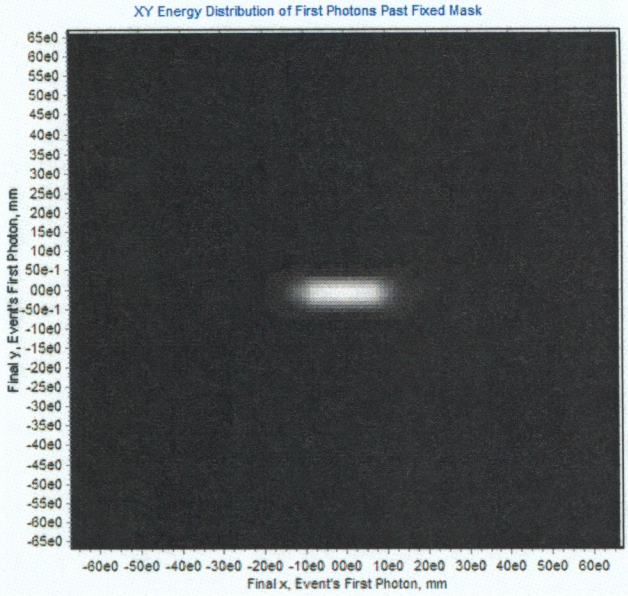
4.5. We performed corresponding simulations for 14.5 GeV electrons, i.e. the Hard X-Ray setting of the FEL. The following plot shows the spatial distribution of energy at the FEE entrance, with no obstructing objects between the undulator and the FEE west wall. The second plot shows the projections of energy onto the X and Y axes. The total energy at this location, when scaled up for a full pulse, is approximately 11.0 millijoules.





4.6. For the final simulation, we insert the Fixed Mask and observe its energy absorption in the first plot below. It absorbs approximately 0.08 millijoules. The second plot shows the spatial distribution of energy just downstream of the Fixed Mask. This represents about 10.9 millijoules. Thus the Fixed Mask will intercept approximately 27% of the spontaneous radiation at the Soft X-Ray setting and only about 0.7% for the Hard X-Ray setting.





4.7. Our conclusion is that, even at the Soft X-Ray setting, there is sufficient energy left in the pulse for alignment, and commissioning the downstream diagnostics.