Failsafe FEL Stopper and Collimator Package *

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Collimators and Stoppers in the XTOD system of LCLS-II serve to confine the FEL beam to the designated beam paths. Because of the potential high intensity of the FEL beam, these Beam Containment system (BCS) devices must be failsafe against FEL burn-through.

A safe working dose of 0.1eV/atom per pulse has been established at LCLS-I for B_4C: the actual dose for burn through is expected to be several times higher but is not precisely known. Conservative calculations for LCLS-II indicate the Stoppers and Collimators may be exposed to doses of up to 0.2 eV/atom for FEL beams with xray energy from 250 to 500 eV, thus there a possible risk of burn-through of B_4C for xrays in this energy range.

This note presents results of calculations of the dose and attenuation within Stoppers or Collimators which have B_4C as the front surface, followed by Aluminum, followed by Air, followed by Tungsten. This arrangement is failsafe in that if the FEL beam where to burn through the B_4C and the Aluminum, it will be attenuated by the Air gap to a point it could no longer burn through the Tungsten.

The main results of the calculation are shown in Table 1. Nominal thicknesses are shown. Any of the thickness may be arbitrarily increased and the devices will still be failsafe. The thickness may be decreased by up to 1 mm and still provide safe beam confinement.

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Table 1: Standard thicknesses for failsafe stopper or collimators for LCLS-II. Actual thickness could be as much as 1 mm smaller.

Material	Thickness [mm]
B_4C	10
Al	3
Air	20
W	80

1 Calculation

There are three sources of input to the calculation.

1. FEL beam size and and shape
2. FEL pulse energy
3. Attenuation properties of the various materials

From these inputs the fluence is calculated at the surface of each material and the maximum absorbed dose per atom is calculated. This calculation is done over the entire photon energy range from 250 to 13,000 eV.

The FEL beam shape is always assumed to be gaussian. The rms of the beam is calculated based on standard FEL theory which results in beam size prediction that are consistent with the smallest observed beam sizes in LCLS-II. The maximum pulse energy is held at 12 mJ. This is based on the maximum pulse energy from the phenomenological estimate from Nuhn. The material properties were interpolated from data taken from CXRO website.

Detailed results are shown in Figure 1. Starting with the plot in the upper left we see that the dose for the B_4C reaches about 0.2 eV/atom at the lowest energies but quickly drops for higher photon energy. The sharp small peaks throughout the plot reflect the range of available combinations of undulator K and electron beam energy that produce the same xray energy. The upper right figure shows the transmitted intensity that gets through the B_4C and is incident on the Al layer.

In the second row, left plot, is the dose calculate for the Al. Because the higher enegy xrays are transmitted through the B_4C the dose in the Al peaks around 0.1 eV near xray energies of 13,000 eV. The main function of the Al layer is to attenuate the higher energy xrays which is shown in the plot in the second row on the right. Here the peak fluence is down by four orders of magnitude.

In the bottom plot on the left is the transmitted intensity that gets through the air gap. Since most of the xrays are hard by this point, nearly all the intensity is transmitted to the W. The final plot, in the lower right shows the calculated dose in the W for the burn-through case — no attenuation in the B_4C or Al layers and only attenuation in the Air gap. There is only significant dose below 450 eV or so. The peak dose is less than 0.1 eV/atom which we presume is also a safe working dose for W.

The thickness of the Tungsten is largely irrelevant to stopping the FEL beam. Because of its high atomic number and density the attenuation length is never more than 6 μm for any photon energy in the range of operation of LCLS-II. The thickness of 80 mm is listed as a nominal thickness because such thick the Tungsten can also be effective in collimating hard spontaneous and bremsstrahlung radiation. In fact, if it only necessary to confine the FEL beam the Tungsten could be replaced a millimeter or two of steel. The attenuation length in steel is not more ant 25 μm over operational photon energy range.

References

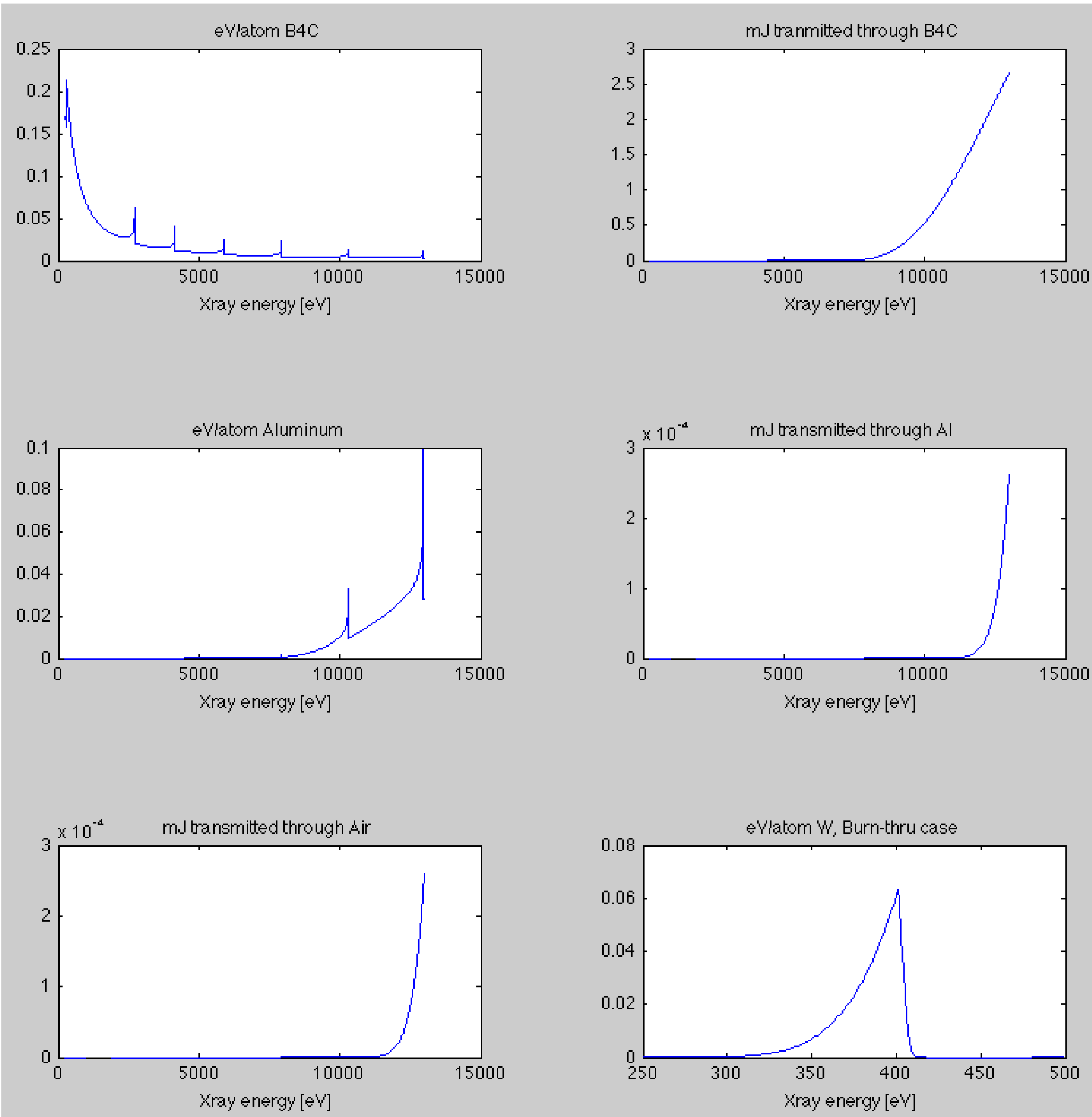

Figure 1: Details calculation fluences and dose for the various materials of the Stopper/Collimator.