Adjustable Aperture Slit Material Selection for LCLS-II *

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Revisions

1. Added SXR only configuration

Introduction

To understand the basis for the material selection of the slits it is useful to consider the function intended for adjustable apertures. In LCLS-II the adjustable aperture has basically the same functions as in LCLS-I, which are

- Define the angular range of spontaneous radiation (SR) for K measurements.
- Allow a study of apertures by making a shadow in the SR that is projected downstream.
- Define a footprint on the offset mirrors for mirror studies.
- Clean up the beam profile by blocking large angle SR without blocking the main FEL beam.

In each of these applications there is not a necessity for the adjustable aperture slits to be able to withstand the highest fluence FEL beams. It is only required that there is good contrast of SR on a downstream YAG screen. The machine protection system can be used to insure that the adjustable aperture slits are not accidentally exposed to high intensity FEL radiation. Nevertheless, when the adjustable apertures are in use, a high-fluence FEL beam will need to be very close to the slits, and it is therefore prudent to make the slits of a design that is reasonably robust against high fluence damage.

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Material Recommendation

Recommended material selections are given for two cases: (1) a design which will accommodate both the SXR and HXR beams, and (2) a design that will only accommodate the SXR design. The SXR design is thinner but will not function well in the HXR beamline, because the high energy photons will penetrate the thin B_4C layer and damage the underlying contrast material.

HXR and SXR Compatible

The simplest recommended package of slit materials for both the SXR and HXR beamlines is given Table 1.The first layer the beam sees, B4C, is thick enough to keep the dose in the aluminum second layer at or below about 0.1 eV/atom . The aluminum is just thick enough to provide better than 1% contrast for SR up to 25 keV. Additional thickness of either layer would work as well.

SXR Only Compatible

The simplest recommended package of slit materials for an SXR-only slit design is given in Table 2. The B_4C is only thick enough to protect the high-Z layer

Table 1: Recommended materials and minimum thicknesses for the slits of the adjustable apertures compatible with both SXR and HXR beams. .

Layer	Material	Thickness [mm]
First	B_4C	15
Second	Al or Si	5

from FEL beams up to about 2500 eV. The high-Z second layer provides adequate contrast for SR.

Table 2: Recommended materials and minimum thicknesses for the slits compatible with only SXR beams. Any element with higher atomic number than tungsten (e.g. Au, Pt) may be substitute for W, provided the mass/area is kept constant or larger.

Layer	Material	Thickness [mm]
First	B_4C	1
Second	W or Ta	0.1

Discussion

The SR spectrum for both the SXR and HXR beamlines is very broad and consists of a fundamental ranging from 250 eV to 13 keV and significantly intense higher harmonics up to more than one hundred keV. However harmonics with energy below about 25 keV are going to interact most significantly with the YAG screen to form an image. For good contrast of SR, we therefore seek materials that will block energies up to 25 keV. Good contrast is assumed to be less than about 1% transmitted to incident intensity ratio.

Any high-Z material can easily provide contrast of 1% or better, but it will also easily be damaged. For this reason a robust first layer of B4C is included. B4C is a well-characterized material, can withstand very high fluences, and is relatively safe to work with. By itself, it can provide good contrast up to x-ray energies of about 8 keV.

For FEL beams with a fundamental in the 8 keV to 13 keV range there is still significant pulse energy transmitted through reasonable thicknesses of B4C. In this region aluminum provides good contrast and absorbs well, but not so well that it is easily damaged, so it makes a good second layer.

For SR with photons energy in the 13-25 keV range and beyond (harmonics) any high-Z material can provide good contrast.

In Figure 1 are the results of a calculation of the transmitted pulse energy and maximum absorbed dose for the slit material package given in Table 1. These calculations are described in Ref [1]. The initial FEL pulse energy was assumed to be 12 mJ and the distance to the source was assumed to be 121 m. This analysis was performed to see how robust the slit package would be against direct accidental FEL beam strike, as well as how much contrast can be expected.

The plots in the first row in Figure 1 show the maximum dose and the transmitted pulse energy for the B4C first layer. FEL beams with a photon energy below 2 keV can cause the dose in B4C to exceed the safe working dose of 0.1 eV/atom. Damage may not actually occur until substantially higher dose, but the limit is not well known.

In the second row are the maximum dose and the transmitted pulse energy for the aluminum second layer. Here the maximum dose is about equal to 0.1 eV per atom so the aluminum is at some risk of being damage by the highest fluence of hardest x-rays and should be protected by the machine protection system.

In Figure 2 the calculation has been extended to 25 keV and demonstrates effective contrast for SR. The net fraction of transmitted beam through the aluminum is less than 1% for all photon energies in this range, which indicate the package provides good contrast of SR.

SXR compatible discussion

In the SXR case the maximum FEL beam photon energy is only about 2 keV so there is relative little

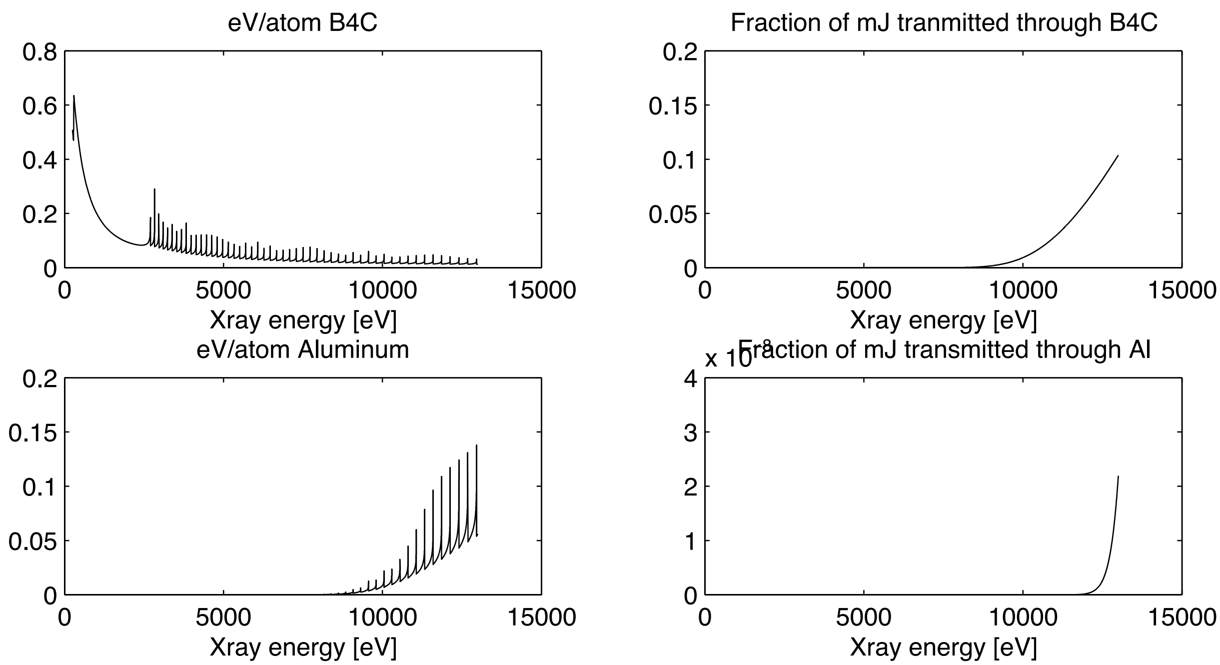

Figure 1: Calculation of fluences and dose for the materials of the slits of the adjustable aperture over the range FEL beam energies.

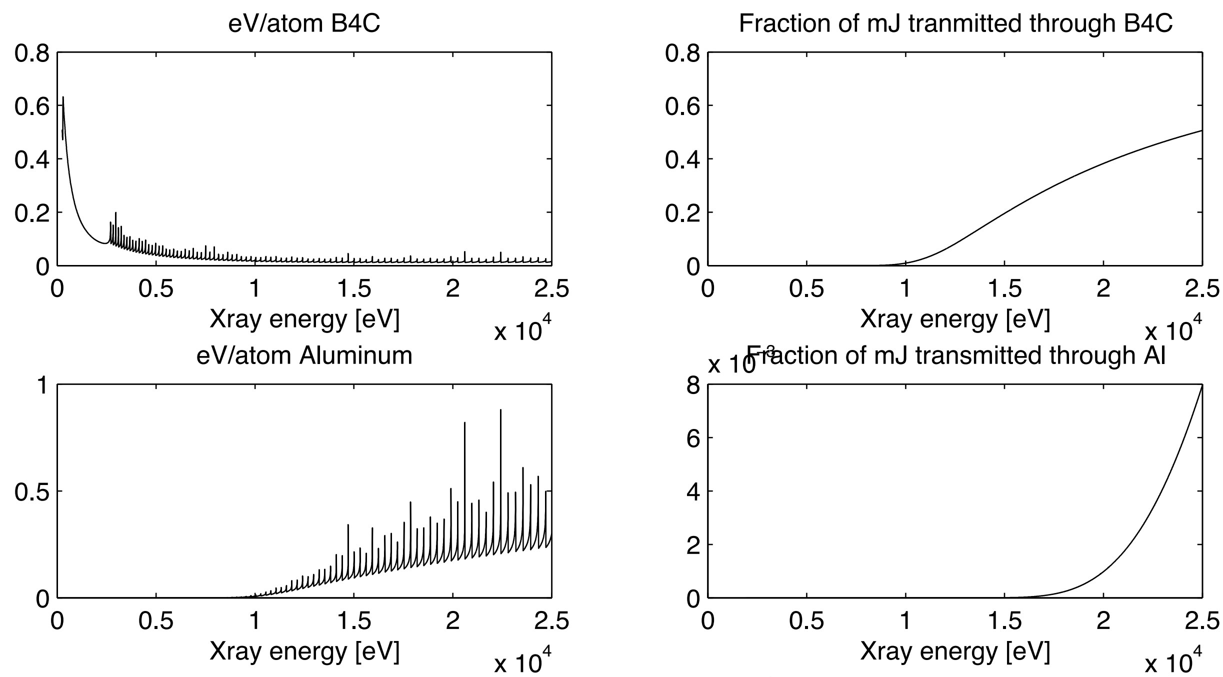

Figure 2: Detail calculation fluences and dose for the various materials of the slits of the adjustable aperture over the range of relevant SR energies.

penetrating high fluence energy to deal with. This means the B_4C layer thickness can be reduced to the point where the transmitted intensity at 2 keV is safe for the underlying material. Good contrast for photon energies up to 25 keV can be provided by a thin layer of high-Z material. See Figure 3 for calculation results for the recommended slit materials. The right-hand plot of the bottom row shows that energy absorbed in a 100 μm YAG screen is less than 0.1 % over the range of harmonics of interest, so good SR contrast is expected.

References

[1] J. Welch, Failsafe FEL Stopper and Collimator Package, June 2012, LCLS-TN-12-2

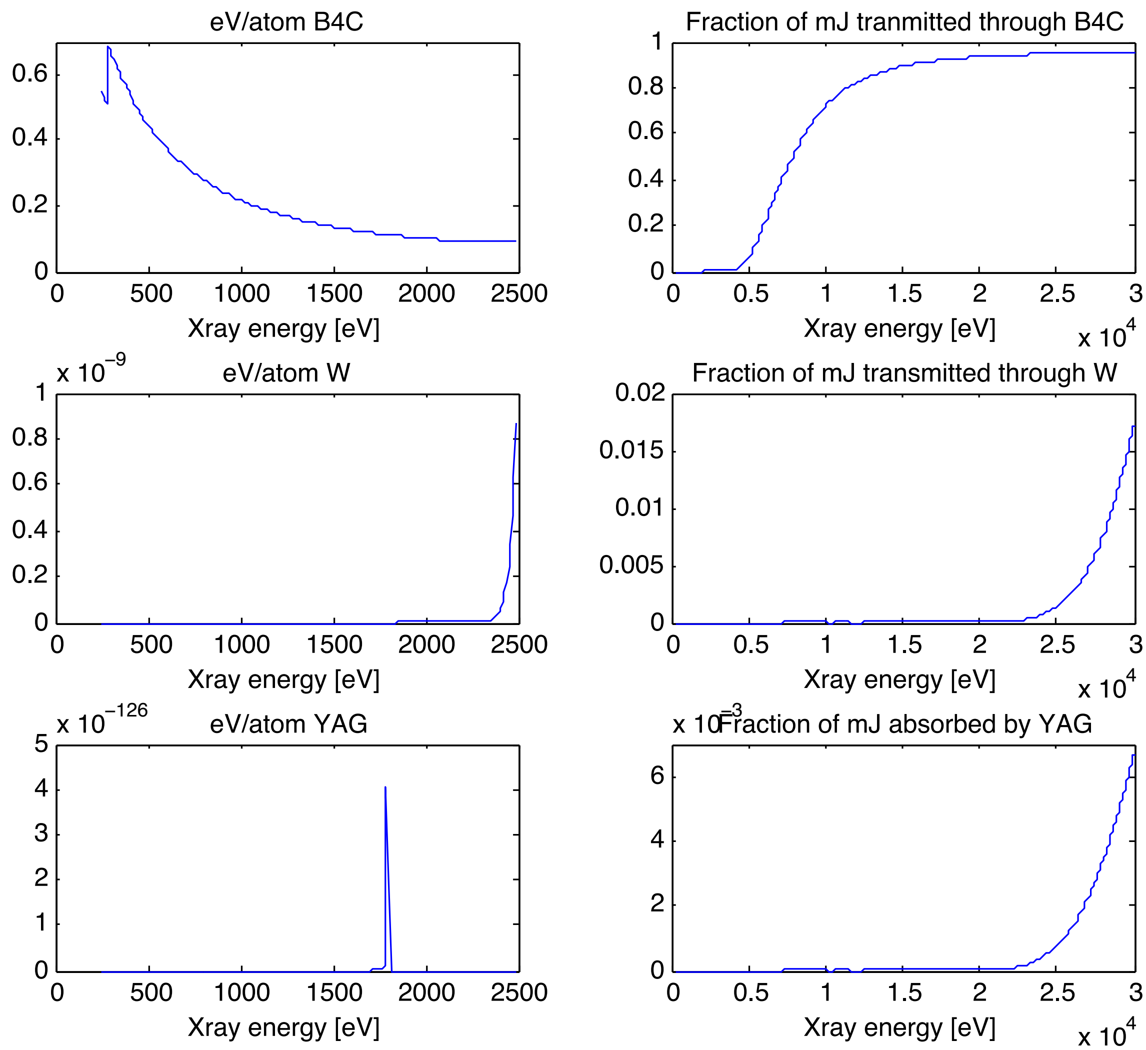

Figure 3: Calculation of fluences and doses for the slit materials for the SXR beam only.