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Mechanical Design

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Abstract

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The particle beam of the SXR (soft x-ray) beam line in the LCLS (Linac Coherent Light Source) has a high intensity in order to penetrate through samples at the atomic level. However, the intensity is so high that many experiments fail because of severe damage. To correct this issue, attenuators are put into the beam line to reduce this intensity to a level suitable for experimentation. Attenuation is defined as “the gradual loss in intensity of any flux through a medium” by [1].It is found that Beryllium and Boron Carbide can survive the intensity of the beam. At very thin films, both of these materials work very well as filters for reducing the beam intensity. Using a total of 12 filters, the first 9 being made of Beryllium and the rest made of Boron Carbide, the beam’s energy range of photons can be attenuated between 800 eV and 9000 eV. The design of the filters allows attenuation for different beam intensities so that experiments can obtain different intensities from the beam if desired. The step of attenuation varies, but is relative to the thickness of the filter as a power function of 2. A relationship for this is $f(n) = x_0 2^n$ where *n* is the step of attenuation desired and x_0 *is the initial thickness of the material*. To allow for this desired variation, a mechanism must be designed within the test chamber. This is visualized using a 3D computer aided design modeling tool known as Solid Edge.

Introduction

Many engineering objectives require the use of Computer-Aided Design (CAD) to further the completion of a design process or project. Several projects will include a Mechanical Design team to develop computer generated representations, or simply models, of the final product. This allows the engineers and scientists to have a visualization of their calculations and a better idea of possible modifications to the overall design. Drafts of the accepted models can also be used as legal documentation between the engineer and the manufacturer if properly dimensioned to the standards of some national or international governing body for geometric dimensioning and tolerancing, such the American Society of Mechanical Engineers (ASME). In many entrepreneurial missions, there is a prototype of the model to have an even better visualization of the design to an actual scale. However, to save resources a three-dimensional CAD model is sufficient.

Recent work with the Mechanical Design department at SLAC deals mostly with modeling and drafting components going in the Linac Coherent Light Source (LCLS) for experimentation; more specifically for the Soft x-ray (SXR) Beam line. Other work includes revising old or incomplete drawings, assisting the LUSI engineering team in designing systems for maintaining its high vacuum environment, and designing other small components as needed by the Mechanical Design department.

One experiment taking place in the SXR Beam line occurs in Section 91-1, where photon tests are placed. Because of the high intensity of the beam many samples are at risk of severe damage, which can compromise the integrity of the results or even destroy the entire experiment. To resolve this filters are placed into the beam line to attenuate the high intensity.

Materials and Methods

Materials

Designing the filters and the other photon experiments required use of a computer aided design tool, Solid Edge. This is a powerful tool that allows a user to make three-dimensional models of a desired product. Another computer tool used is Windows Excel. The materials used for the filters are chosen based on past trial and error analysis. Currently the filters are made of Beryllium or Boron Carbide.

Methods

There are certain constraints placed on determining acceptable materials used as filters for the photon beam. First the range of photon's energy being attenuated is from 800 eV to 9000 eV. This is not so much as a limit as it is a parameter of the beam itself. However, it designates the range for which it must be attenuated. Another constraint is the thickness of the filter. Generally metals are denser than ceramics, so we must keep the metals at a lower thickness. This is due to how tightly packed the metal structure is compared to ceramics. A photon is more likely absorbed if space between each compound decreases, thus a smaller thickness is needed to for the attenuation. The ceramics have a more relaxed constraint. For this design 10 microns is acceptable by a metal acting as a filter; 100 microns is acceptable for a ceramic. It just so happens this correlates perfectly with the attenuation we require, which is the third constraint. If we go anywhere below 10 attenuations, then the material becomes too thin for the beam and would have little to no effect. If we go above 100, then the material is too thick and should no longer be treated as a filter, but more so as a thermodynamic plate.

Results

It was determined that a relationship can be used to determine the transmission of the photons traveling through the particles. The distance that a particle travels before its probability of being transmitted decreases by a factor of 1/*e* is known as the attenuation length or the absorption length [2]. This probability can also be accepted as evidence for determining the depth at which the particles are absorbed because of the Beer-Lambert Law [6]. Given as: $P(x) = e^{-x/\lambda}$ where *x* is the depth of the particle, and λ is the distance into the material when the probability of being transmitted drops to 1/*e* . What has been determined from the intensity of the beam at 800 eV can be seen in Table 1. Beryllium at 20 microns successfully attenuates the beam for attenuation factor of 0.01. Until the attenuation reaches 0.10, Beryllium will stay successful. Table 1 also shows that Beryllium fails when the beam energy is at approximately 986 eV. This is the range at which Beryllium is acceptable at this depth of a filter for the beam. Further ranges of Beryllium are accepted for higher energies as the thickness doubles. This is interesting in that we want attenuations from 10 microns to 100 microns (0.01 and 0.10) and we effectively get a range that is covered by the thickness as a function of $f(x) \propto 2^x$, so that any initial thickness that you choose can simply be multiplied by any power of 2. The expression for this, if we say that our initial thickness is x_0 and our desired attenuation band is *n* power of 2, is: $f(n) = x_0 2^n$. This is still governed by the boundaries of attenuation factors between 0.01 and 0.10. Once one range fails, another thickness can be chosen using the above expression. This is expressed more clearly in Figure 1. However, there is a point at which materials change and Boron Carbide is used to complete the process. The reason for this is that the thickness of Beryllium becomes too great and it is more beneficial to use another material. Because Boron Carbide is the only other known material to survive the intensity of the beam, we use an additional 3 filters of Boron Carbide to finish. The analysis for this is found in Figure 1. The energy range that each filter covers increases because this data was acquired on a log scale.

Designing the holder for all of these filters is another aspect of the design. Because of the thinness, these filters cannot be poked or probed. The other limitation is having a holder that can fit inside the current test chamber without striking the bottom causing the chamber to crack and ruin the vacuum equipment. The last requirement limits the distance the samples have between each other and how many can go in the chamber at once. The holder should be universal for other experiments to take place on the same section of the beam line.

What was done to achieve most of these requirements was to design a two-legged fork with a series of threaded holes. This would allow for washers to hold the filters in place and use the force of the screw to keep them clamped down. The filter strips would be ordered at 1 inch long and ¼ inch tall. This limits the number of filters that can be placed in the test with another sample. Fortunately, this is not required and all of the filters can be placed. In Figure 2, a better visualization is seen for a better idea of what the fork looks like. The holes holding each filter are #2-56 UNC 2B threaded holes. Washers are placed on the face of the fork to clamp the filters in place. There are 15 places in total. In figures 3 and 4, the fork is attached to its translator assembly and placed in the test chamber.

Conclusion

It is important to savor the integrity of soft x-ray experiments, and any experiment in high-energy physics. Data trials can sometimes only be taken once or twice, so it is necessary for the experiments to be treated with the highest delicacy. Whether or not the research is successful will be proven later on in the summer. It is likely that a more efficient system will be developed and the trials for this method might not ever occur. However, the work done here will be vital in developing new techniques for attenuating high intensity beams.

Future Work

Once more research and testing is done on these filters, work can begin to reduce the number of filters allowing a greater range of energies attenuated. The issue with using anything other than Beryllium and Boron Carbide is that anything heavier will have too small of an absorption length. The issue here is finding companies willing or able to produce such small thicknesses. Based on current research, many carbide materials should be effective, as they would have an equal number of carbon atoms as the number of heavier metal atoms

References

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Acknowledgements

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Figures and Tables

MATERIAL:	**Be**				
			THICKNESS:	**20**	**microns**
	PHOTON ENERGY (eV)	**ATTN LENGTH (microns)**			
				TRANSMISSION	
	800	4.66859		0.01378811	
	803.882	4.73582		0.014652659	
	807.783	4.80401		0.01555787	
	811.703	4.87319		0.016505067	
	815.641	4.94338		0.017495443	
	819.599	5.01458		0.018529895	
	823.576	5.08679		0.019609274	
	827.573	5.16006		0.020735171	
	831.588	5.23439		0.021908413	
	835.624	5.30978		0.023129778	
	839.679	5.38626		0.024400501	
	843.753	5.46382		0.025721124	
	847.847	5.54251		0.027093175	
	851.961	5.62233		0.028517308	
	856.096	5.7033		0.029994486	
	860.25	5.78543		0.031525454	
	864.424	5.86875		0.033111298	
	868.619	5.95327		0.034752693	
	872.834	6.039		0.036450264	
	877.069	6.12597		0.038204992	
	881.325	6.21395		0.040012448	
	885.602	6.30293		0.04187244	
	889.899	6.39318		0.043790708	
	894.217	6.48472		0.045767857	
	898.556	6.57756		0.047804227	
	902.917	6.67174		0.049900775	
	907.298	6.76726		0.052057527	
	911.701	6.86416		0.054275356	
	916.125	6.96246		0.056554646	
	920.57	7.06216		0.058895255	
	925.037	7.16328		0.061297448	
	929.526	7.26584		0.063761436	
	934.036	7.36986		0.066287379	
	938.569	7.47572		0.068884259	
	943.123	7.58433		0.071574525	
	947.7	7.69451		0.074328871	
	952.298	7.8063		0.077147722	
	956.919	7.91971		0.080030698	
	961.563	8.03477		0.082977865	
	966.229	8.15149		0.085988719	
	970.917	8.2699		0.089063211	
	975.629	8.39002		0.092200978	
	980.363	8.51189		0.095402125	
	985.12	8.63554		0.098666446	

Table 1: Particle Transmission for Beryllium film at 20 microns thick. The attenuation lengths are calculated based on [5].

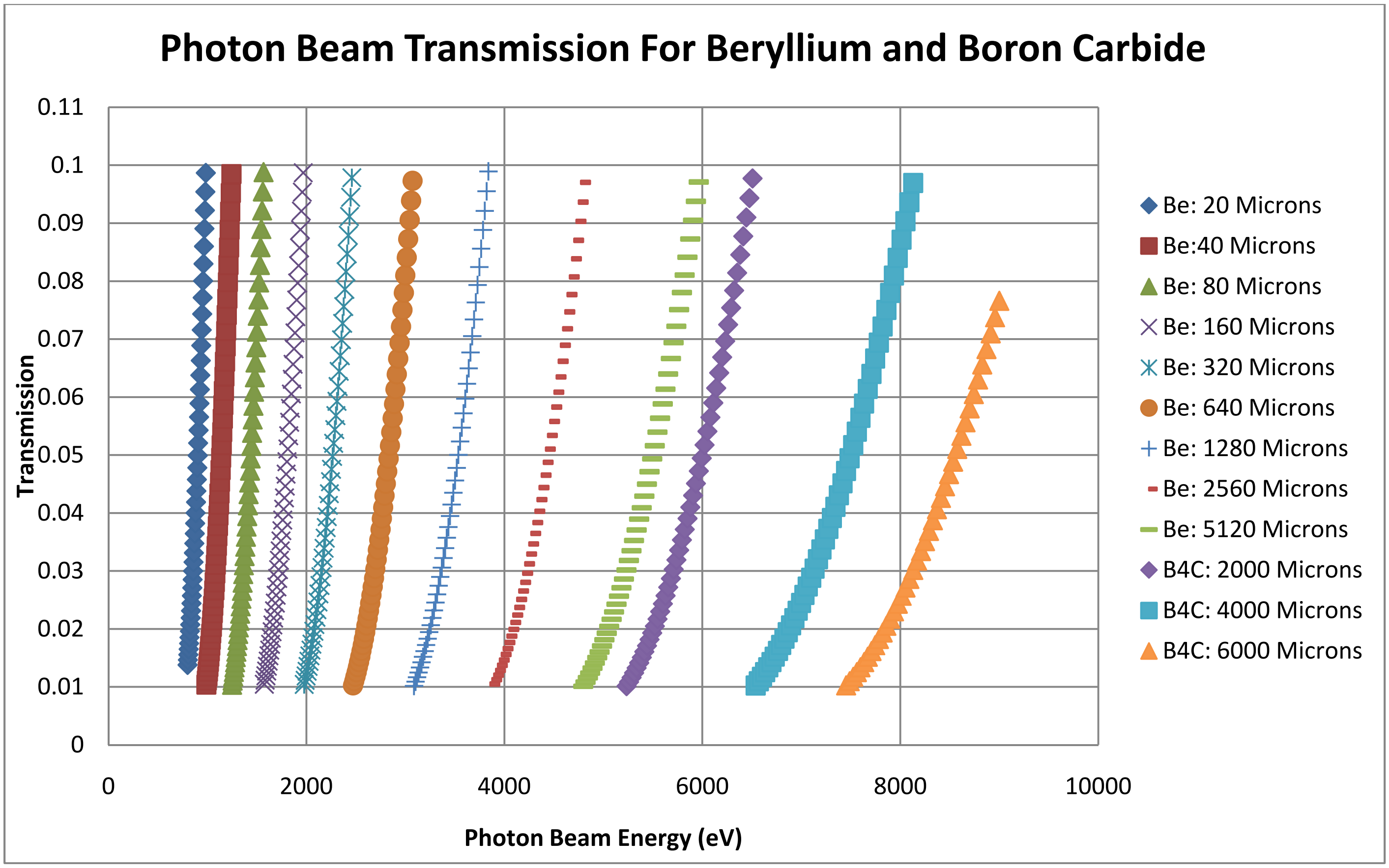

Figure 1: Data Plot of the Photon Transmission for Beryllium and Boron Carbide. Shows the transmission range and the energy ranges for each thickness of filter.

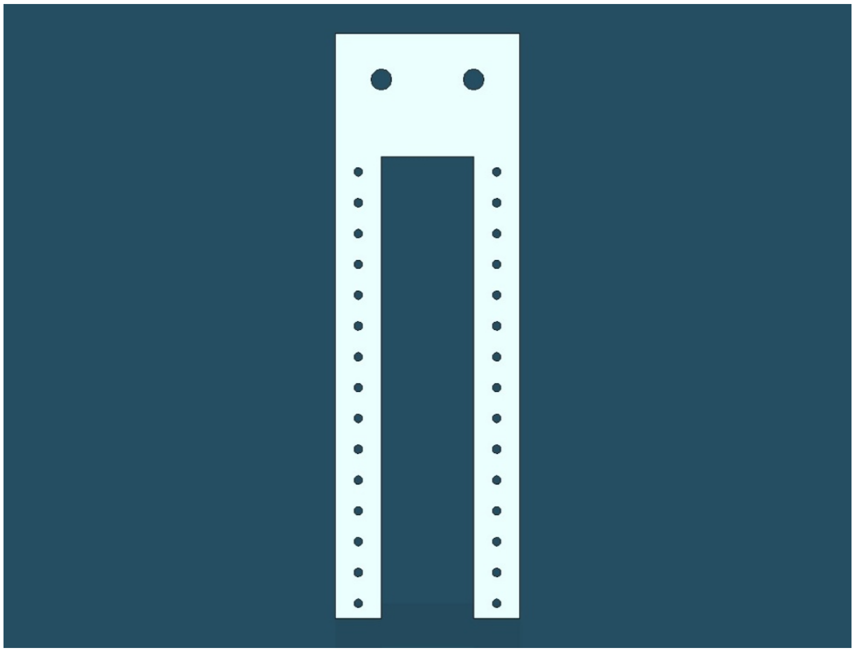

Figure 2: Filter Fork Holder with 15 spaces for #2-56 UNC threaded screws and washers.

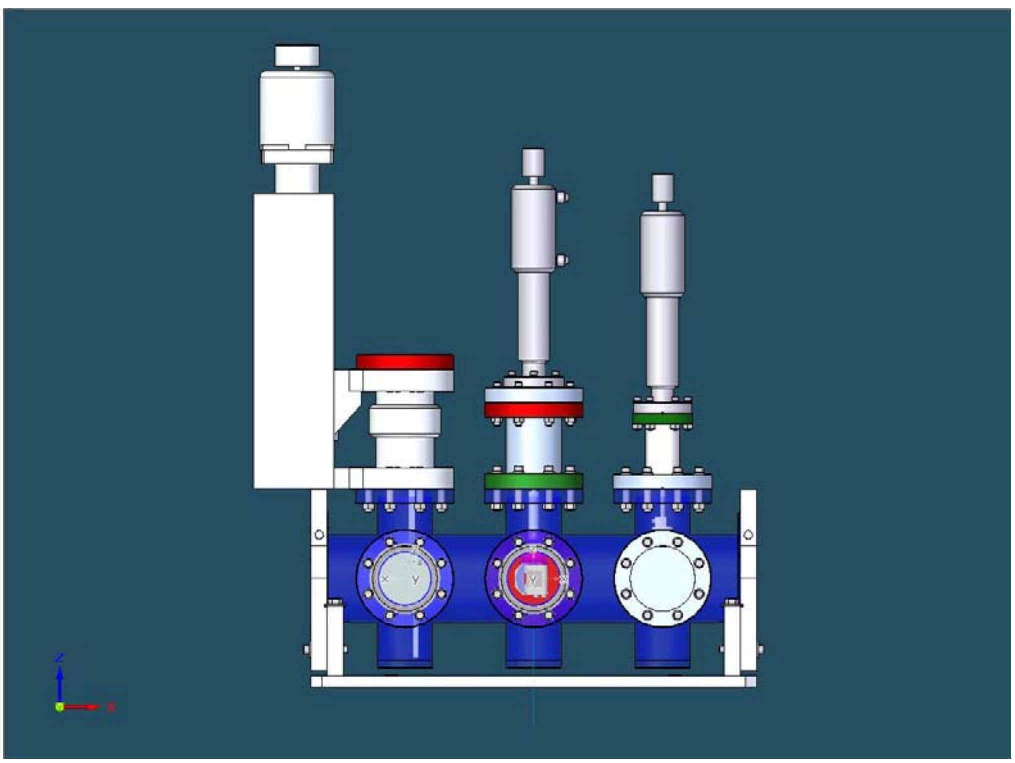

Figure 3: Filter Fork Holder Assembly placed in the ST-0 replacement test chamber. The Fork assembly is located in the chamber 1, furthest to the left.

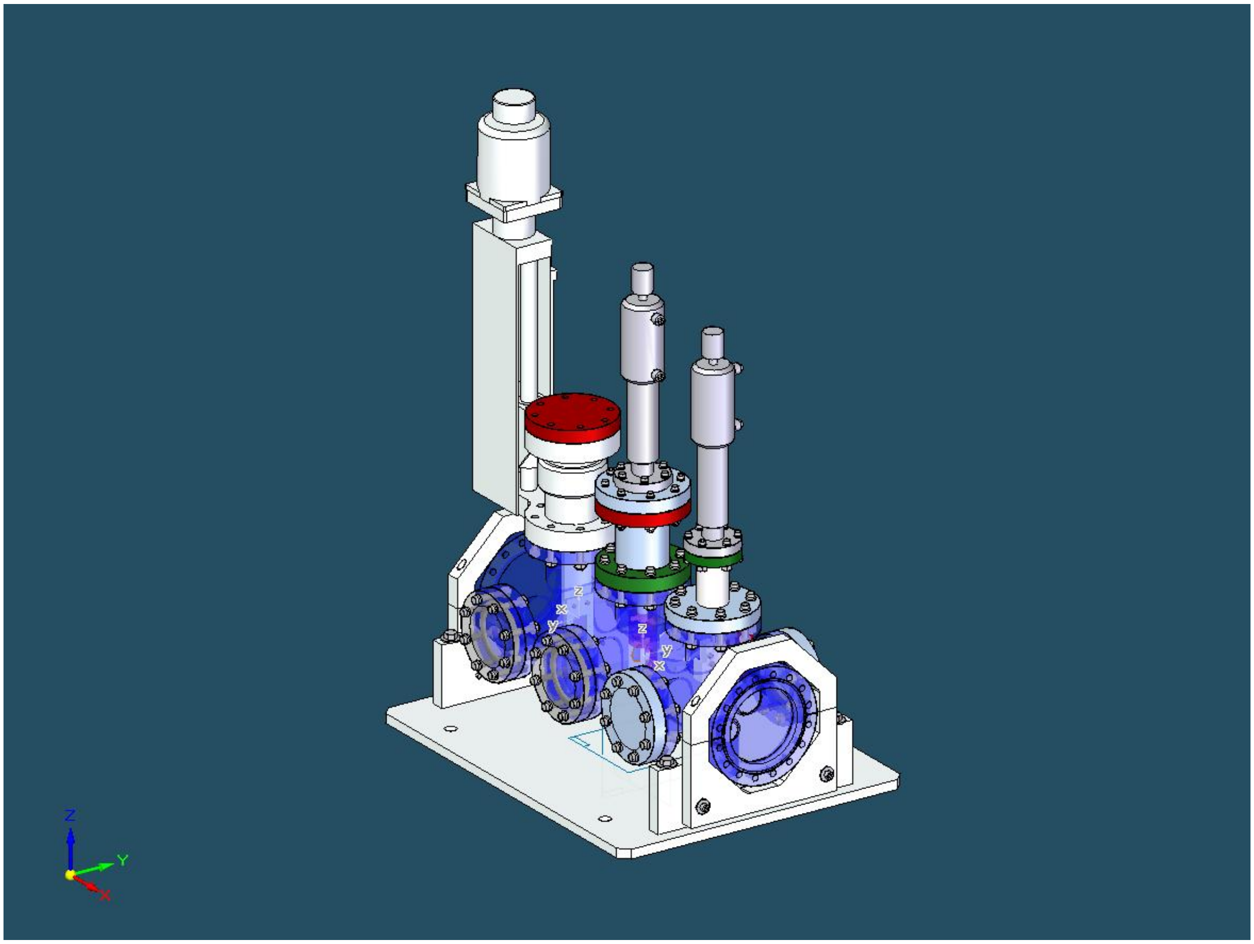

Figure 4: Filter Fork Holder Assembly in an isometric view relative to the other photon tests and the beam line direction. Beam line is along x-axis based on the coordinate system to the left.