# LCLSII FEL photon beam containment system

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## Introduction

LCLSII will produce powerful and collimated FEL photon beams. Unlike conventional synchrotron, the LCLSII beam containment components withstand not only the high integrated beam power and power density, but also the instantaneous thermal shocks from the pulsed beam structure, which can potentially reach 9mJ/pulse. With beam repetition rate up to 1MHz, regular metal based beam collimators and absorbers used in synchrotron can no longer work, because of the likelihood of fatigue failure. And because of the poor thermal conductivity, the old LCLS B4C based absorber is also not practical. Hence, a low-Z and high thermal conductivity CVD diamond based photon beam collimator and absorber systems have been developed in LCSLII. The initial damage tests using LCLS FEL beam provided positive results that graphite coated CVD diamond can endure per pulse dose level to 0.5eV/atom. For the beamline and personnel safety, in addition to the passive CVD diamond collimators and absorbers, newly developed photon diode beam mis-steer detection systems and conventional SLAC pressurized gas burnt-through monitors have been also introduced in the photon beamline system design.

## LCLS-II Beam parameters

**LCLS-II Soft X-ray Beam parameters at 0.1MHz, 300pC**

| Energy [eV] | Beam divergence [µrad] | Max integrated power [W] | Max single pulse fluence [mJ] |
|---|---|---|---|
| **250** | 41.1 | 101.5 | 8.8 |
| **750** | 750 | 1500 | 5.7 |
| **1250** | 4.8 | 2.8 | 3.4 |

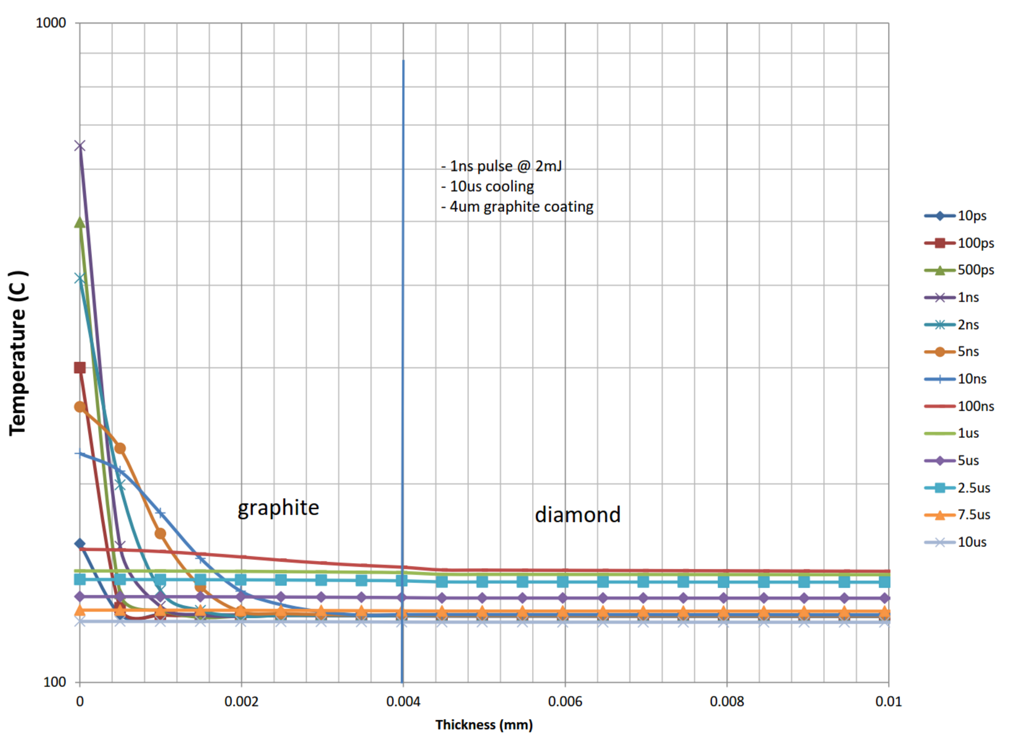
**LCLS-II Hard X-ray Beam parameters at 0.3MHz, 100pC**

| Energy [eV] | Beam divergence [µrad] | Max integrated power [W] | Max single pulse fluence [mJ] |
|---|---|---|---|
| **1500** | 2.8 | 519 | 1.73 |
| **3250** | 2.0 | 185 | 0.62 |
| **5000** | 3.3 | 1.8 | 0.06 |

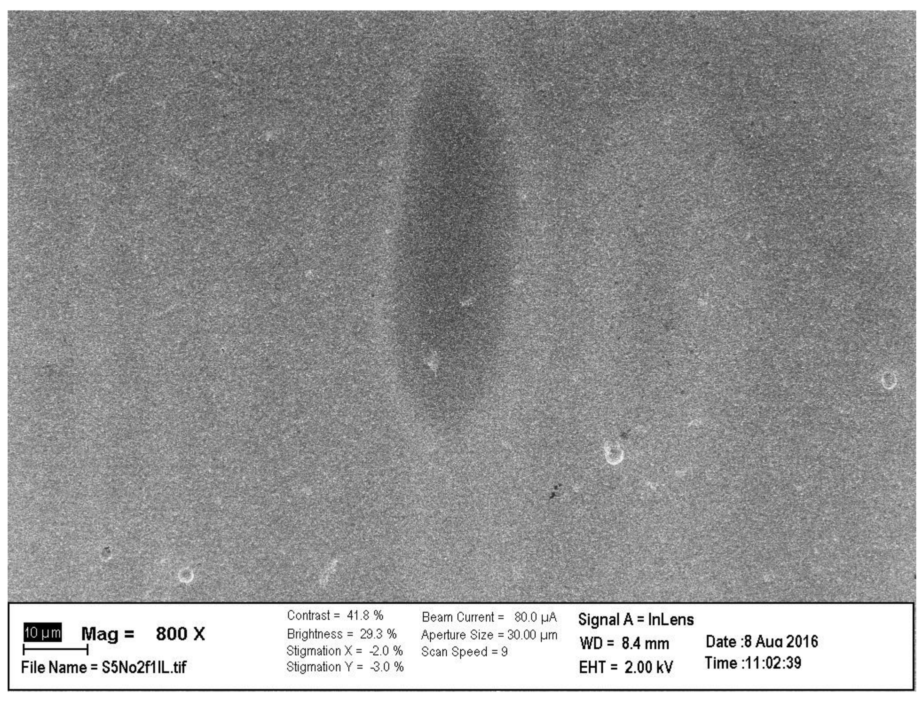
For some extreme cases, power density on the beam containment element can be up to 1000 W/mm². For soft x-ray beamline, single pulse may even induce damages that are not purely due to thermal effects, but directly breakdown of the bond between atoms.

## Graphite coated diamond

To further improve the thermal shock resistance, a thin pyrolytic graphite is coated on all sides of the diamond used in collimators and stoppers. Figure below shows the transient behavior of a single pulse hit the diamond absorber with 4µm thick graphite coating. One can see that the sharp instantaneous temperature rises are located in the thin graphite coating. The temperature in diamond doesn't have this sharp rise. One of the damage tests done to the graphite coated diamond by taking LCLS beam with a fluence of approx. 0.6±0.15eV/atom. After 100,000 shots, one can visually observe the footprints of the beam, but no obvious morphological damage to the coating.




*Single pulse transient thermal in graphite coating to diamond*

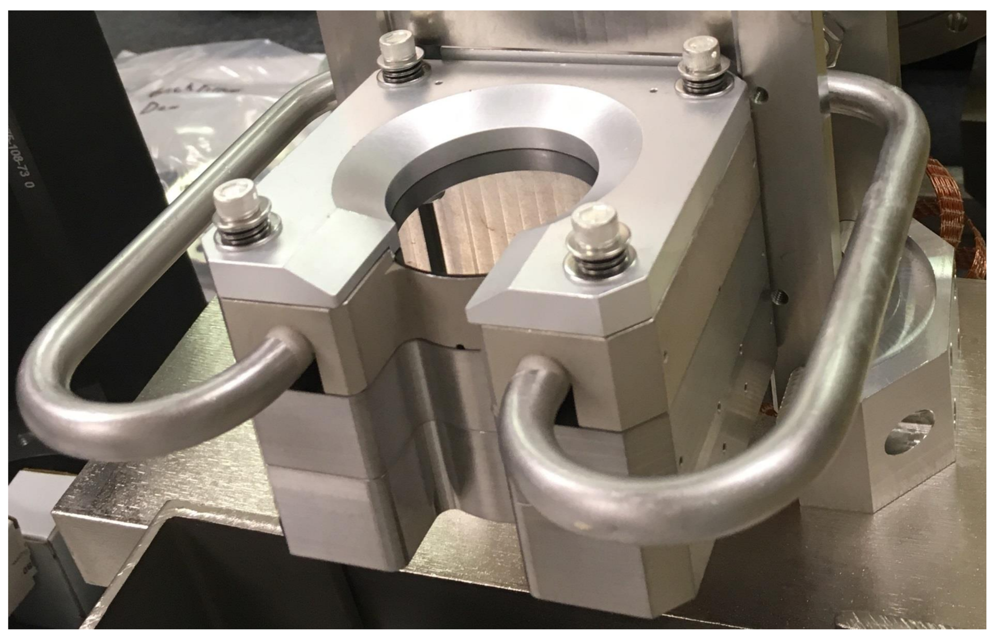



*Damage test, 0.6eV/atom, graphite coated diamond*

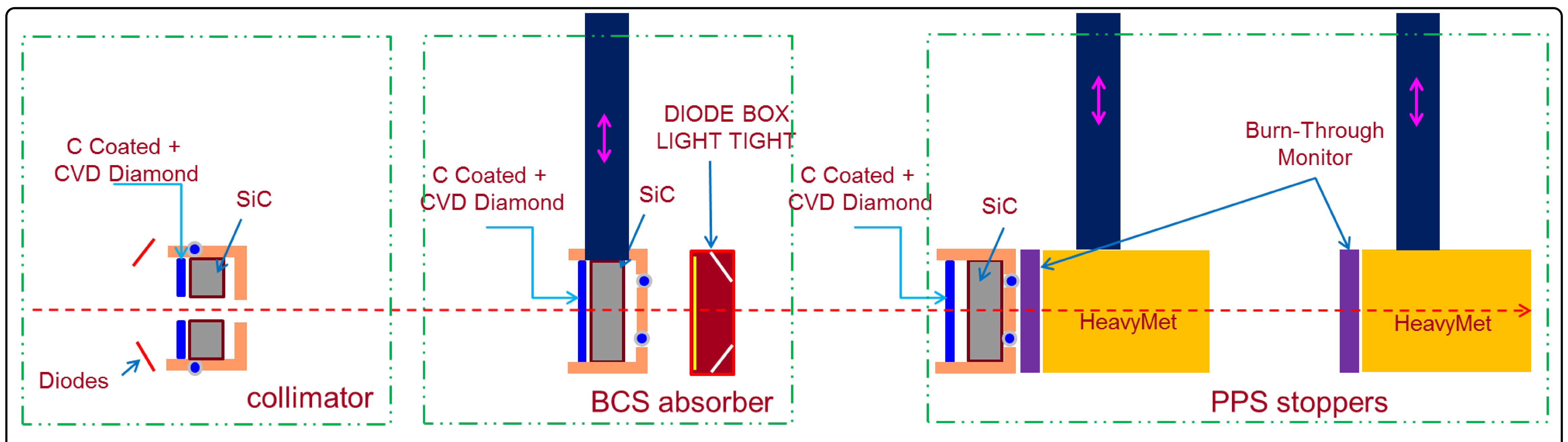
## Photon Beam containment system (BCS)

Thermal absorbers are major elements of a BCS. Even equipped with graphite coated diamond absorbers, under extreme conditions, the thermal elements won't survive the extreme heat loads and ablations. Under normal operation conditions, the photon beam will stay clear from the collimator apertures, and will only take the beam when abnormal mis-steered conditions occur. Hence, BCS needs to detect the beam mis-steering conditions, and minimize duration of the ablation time. To address this problem, a diode based sensing system is employed to provide fast feedback to shutdown the hazard as soon as it happens.

To stop the beam from going downstream to the experimental stations, a redundant pair of diamond absorbers are integrated with the heavy metal for personal safety (Figure below). In the first absorber assembly, a fast diode based sensing system is kept in a light-tight box to detect any possible breaches of the diamond absorber. In the second absorber assembly, a gas based burnt-through monitor (BTM) is sandwiched between the absorber and the heavy metal block. In case the photon beam breaks the absorbers and melt a hole on BTM chamber, the bleeding of gas will cause a pressure drop and in turn it will be trip the beam off by shutting down the RF directly



*Absorber assembly with graphite coated diamond and light-tight box*




*Schematic layout of LCLSII beam containment system*

## Summary

Diamond coated with graphite is a feasible solution to absorb and stop LCLS-II FEL beams, therefore, it has been used to construct the photon collimators and stoppers as major part of the beam containment system. Safe operation conditions have been estimated and mapped with input powers and photon energies.

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