SIMULATION OF THE BEAM DUMP FOR A HIGH INTENSITY ELECTRON GUN

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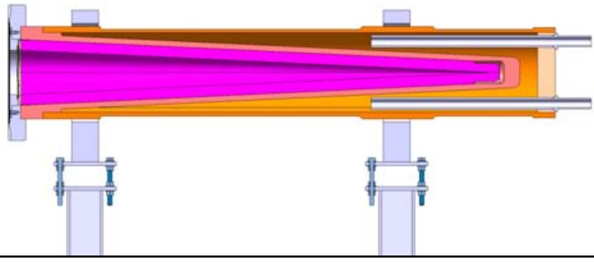
Abstract

The CLIC Drive Beam is a high-intensity pulsed electron beam. A test facility for the Drive Beam electron gun will soon be commissioned at CERN. In this contribution we outline the design of a beam dump / Faraday cup capable of resisting the beam's thermal load.

The test facility will operate initially up to 140 keV. At such low energies, the electrons are absorbed very close to the surface of the dump, leading to a large energy deposition density in this thin layer. In order not to damage the dump, the beam must be spread over a large surface. For this reason, a small-angled cone has been chosen.

Simulations using geant4 have been performed to estimate the distribution of energy deposition in the dump. The heat transport both within the electron pulse and between pulses has been modelled using finite element methods to check the resistance of the dump at high repetition rates. In addition, the possibility of using a moveable dump to measure the beam profile and emittance is discussed.

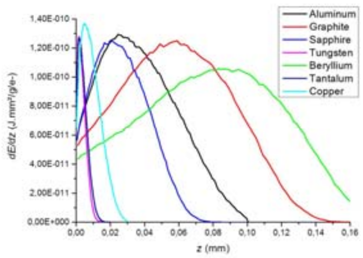


Energy Deposition

Relevant parameters of the electron gun test stand for the CLIC Drive Beam:

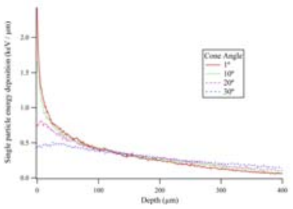
Beam Energy	100 – 140 keV
Beam Current	4.2 A
Pulse Length	150 µs
Pulse Population	4 x 10^{15} e^-
Pulse Energy	88 J
Repetition Frequency	1 - 50 Hz
Beam Emittance	12 mm mrad

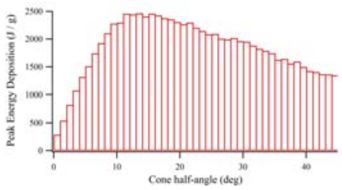
The high beam current means that stopping the beam is not trivial. Low energy electron beams are stopped very quickly in almost all materials, so the density of energy deposition close to the surface is extremely high. Thus, a beam dump must be designed to safely absorb the beam by distributing the heat load over as large a surface as possible.



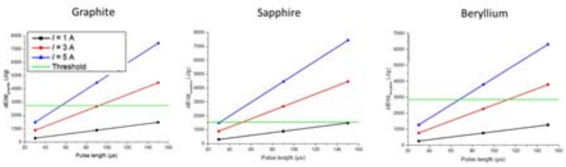
Energy deposition vs depth, for a 140 keV electron beam hitting various materials at normal incidence

Although graphite has the best performance, it cannot withstand the beam at normal incidence. Instead a shallow cone is used to distribute the beam over a large surface. When the beam is incident at a small angle, the energy deposition layer becomes even shallower, due to the large proportion of electrons which are scattered out of the graphite and re-incident at another point. (**left**). However, since the beam is spread over a larger surface, it is still better to have a small angle <5° (**right**).





Material Choice



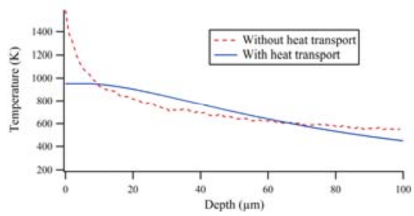
The high specific heat capacity, which also rises with temperature, means that graphite can accept 7.9 kJ / g before reaching its sublimation point. In reality, however, the stress caused by the sudden thermal expansion would destroy the graphite at a much lower temperature. However it is estimated that the repeated stress cycles will reduce the dump lifetime if the single-shot temperature rise exceeds ΔT≈1100 K.

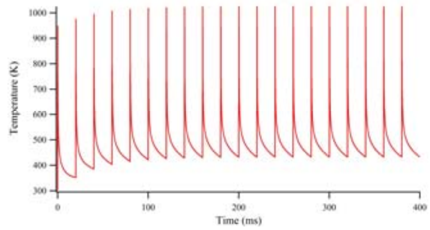
Thermal properties of amorphous graphite:

Density	1.8 g / cm^3
Specific Heat Capacity	0.76 J / g K
Thermal Conductivity	100 W / m K
Thermal Expansion Coefficient	4.0 x10^{-6} / K
Sublimation Temperature	3900 K

Thermal Simulations

Because the energy is deposited in such a thin layer, conduction within the 140µs pulse is important. The temperature profile at the end of a single pulse is shown on the right, with and without the effect of conduction.



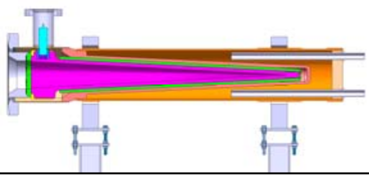


Even when operated at 50Hz, an equilibrium is quickly reached, and the maximum temperature is not significantly higher than the single-shot case.

Dump Instrumentation

Three solutions are being considered for beam current measurement at the dump:

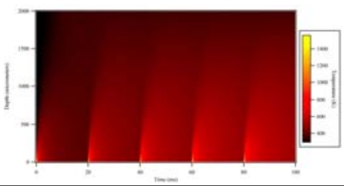
1. *Isolate the whole dump*
2. *Isolate the graphite cone by using a thin layer of Shapal (a ceramic which is an electrical insulator but has good thermal conductivity)*
3. *Place a beam current transformer at the entrance of the dump.*



Beam dump with isolated graphite cone for beam current measurement.

Magenta: graphite;
Green: Shapal;
Orange: copper

During the second stage, emittance measurement will be added using a moveable slit. A slit which is currently in use for the Linac4 commissioning will be available. The slit blades consist of graphite plates angled at 15° to the beam and mounted on a cooled copper block. The simulations suggest that the single-shot temperature rise would be too great to use this slit at the CLIC DB test stand. However, it may be used with a reduced pulse length.



Temperature profile of the graphite exposed to 5 pulses

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