

# A BEAM LINE HOM ABSORBER FOR THE EUROPEAN XFEL LINAC

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## Abstract

High frequency Higher Order Modes propagating in the beam line of a superconducting linac carry big fraction of the energy deposited by an accelerated beam. In this contribution we describe the design of beam line absorbers which we plan to install between cryomodules to dissipate the propagating energy in 70 K environment. Experiments with absorbing material and mechanical and thermal modeling of the absorber are presented in the paper.

## INTRODUCTION

The superconducting driving linac of the European XFEL facility [1] will deliver very short bunches of  $\sigma_z = 25 \mu\text{m}$  at maximum energy of 25 GeV to the insertion optical devices. Their nominal charge will be 1 nC and their intra-pulse repetition frequency will be 5 MHz. The nominal RF-pulse repetition rate is assumed to be 10 Hz. Fig. 1 illustrates the frequency spectrum of the nominal beam, which due to the very short longitudinal length of bunches reaches high frequency up to 5 THz. The integrated longitudinal loss factor of the TTF type cryomodule housing eight 9-cell cavities is 135 V/pC. The total deposited power by the nominal beam (40000 bunches/s) is 5.4 W if no synchronous excitation takes place [2]. Its distribution for various frequency ranges is shown in Fig. 2. The modes below the cut-off frequency are suppressed by coaxial HOM couplers [3] attached to each cavity. A big portion (~80%) of the propagating power will be dissipated in the beam line absorbers to

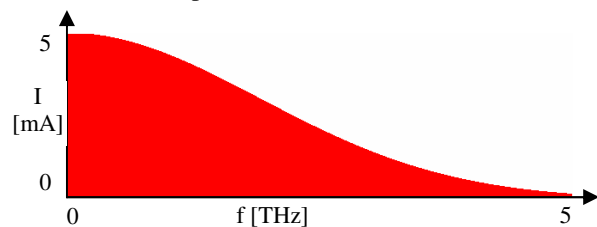


Figure 1: Spectrum of the nominal XFEL beam

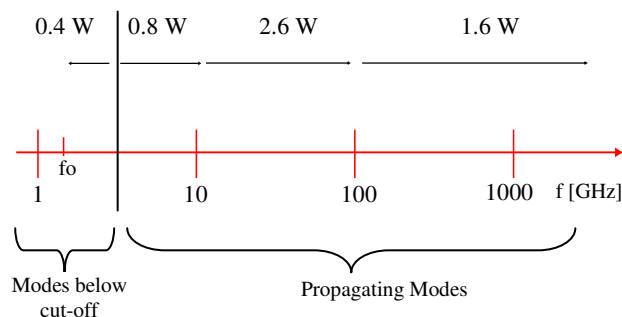


Figure 2: HOM power distribution vs. frequency for the nominal pulse operation.

mitigate additional cryogenic load at 2 K. These devices installed between cryomodules will absorb the power and transfer the generated heat to the 70 K environment. In the absorber design we take into account a possible upgrade of the XFEL facility to higher average brilliance by operating it with more bunches in cw or near-cw modes [4]. For this, the absorber power capability has been specified to 100 W which will allow for acceleration of up to one million nominal bunches per second.

## MODELING AND TESTS

The proposed layout of the absorber is shown in Fig. 3. It is integrated into the vacuum chamber connecting two cryomodules. The absorption of microwaves takes place in the ceramic ring hanging on the brazed copper stub. The dissipated energy is transferred to the 70 K cryostat shield via the stub and its external thermal connection. A stainless steel bellows serves as thermal barrier between the 70 K level of the flange and the 4 K cold vacuum chamber. The ceramic material adopted for this design is used in HOM dampers installed in CEBAF at JLab. RF properties of the ceramics have been measured at room

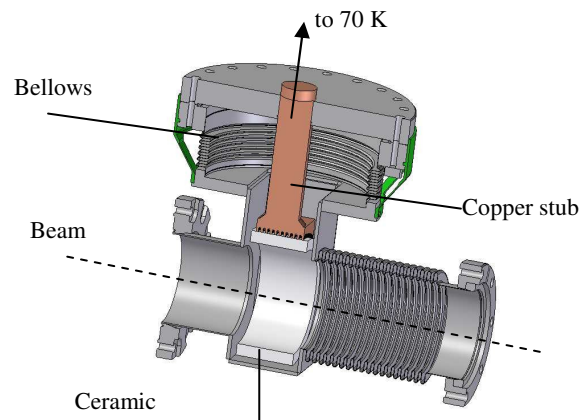


Figure 3. Layout of the beam line absorber.

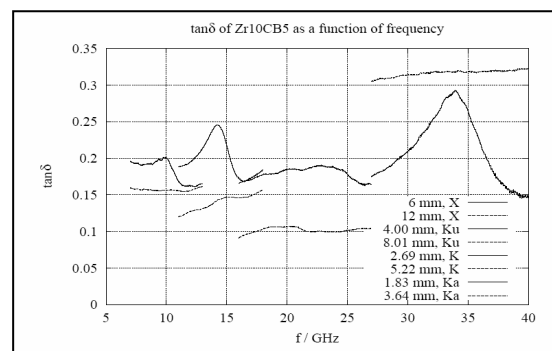


Figure 4. Loss tangent of the ceramics as measured at room temperature [5].

temperature as function of frequency (Fig. 4). The absorption of propagating microwaves was proven for this ceramic material in the test carried out at the TTF linac in 2002 and reported later in [2].

### Heat conductivity and temperature gradient

The specific heat conductivity  $\Lambda$  vs. temperature for two ceramic samples was measured recently. The result is displayed in Fig. 5. The ceramic ring of the proposed design has an inner diameter of 80 mm, a wall thickness of 10 mm and a length of 50 mm. For this geometry and the specific heat conductivity we have calculated the temperature gradient and heat flow by means of ANSYS code. The modeling was performed for the worst case scenario when 100 W of power is dissipated in the ceramic. The calculated temperature distribution is shown in Fig. 6. The maximum expected temperature difference  $\Delta T$  across the ceramics and copper stub is 110 K.

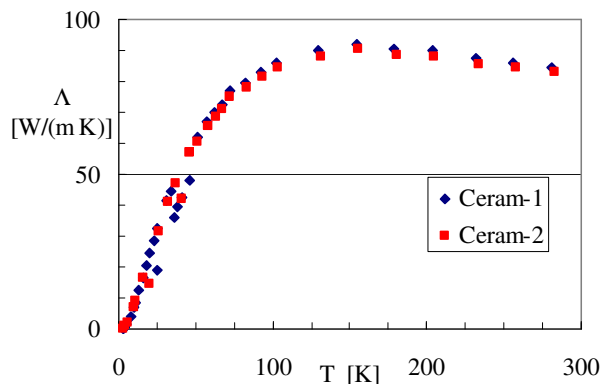


Figure 5. Specific heat conductivity  $\Lambda$  of the ceramics as function of the temperature.

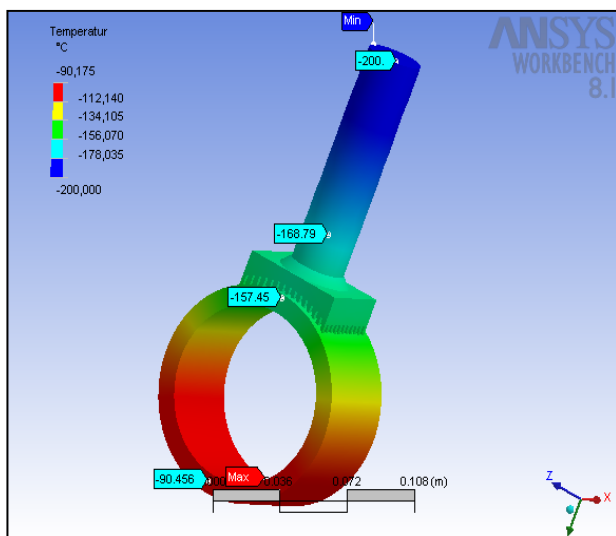


Figure 6. Calculated temperature distribution in the cold absorber for power dissipation of 100 W.

### Thermal tests

The mechanical properties of the brazed connection are of concern because the thermal expansion coefficients of

the ceramics and copper are very different. To reduce the forces after cool down the bottom part of the copper stub will be cut in with a pattern of 2 by 2 mm with a depth of 3-4 mm. The pattern can be seen in Fig. 7, which shows our experimental setup with two brazed stubs to test the mechanical properties of the brazing. At first, the ring with the two stubs was cooled down very fast to 70 K and warmed up to 300 K. The fast cooling down was done three times. No mechanical change was observed after these cycles. In a second test we immersed one of the stubs in liquid nitrogen and heated the other one to create  $\Delta T$  of 140 K across the ceramics and the copper stub, slightly more than the value we expect for 100 W of dissipated power. The setup was kept for several hours with this temperature gradient and also this time we did not notice any mechanical change in the brazing after warm up. Finally the setup was several times cooled down quickly to 4 K using liquid Helium without any mechanical change.

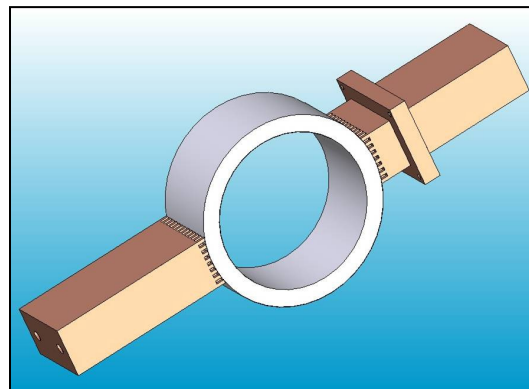


Figure 7. Experimental setup with two brazed stubs for thermal tests.

All three tests confirmed that neither many thermal cycles between 4 K or 70 K and 300 K nor 100 W of dissipated power will change the mechanical properties of the brazing between the ceramic ring and the copper stub.

### PROTOTYPE AND FURTHER TESTS

The first prototype will be ready by the end of October this year. We plan to install it in the TTF linac in 2006 to prove its efficiency in absorption of the propagating part of the TTF beam spectrum. Additional to the absorption we will be able to measure the static and dynamic heat leaks to the 2 K environment. For this purpose, the prototype will be equipped with several temperature sensors. The beam test will also give information how the radiation affects the absorber in a long term beam operation.

### ACKNOWLEDGMENTS

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