BEAM TESTS OF HOM ABSORBER AT FLASH

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Abstract

High frequency Higher Order Modes (HOM) propagating in the beam line of a superconducting linac can carry a substantial fraction of the energy deposited by the beam in accelerating structures. In this contribution, we report tests results of the beam line absorber (BLA), which was designed and fabricated at DESY, and installed in the FLASH accelerator to absorb the propagating HOM energy generated by high current beams. Two tests were carried out, in September 2008 and September 2009, during so called high current runs. The experiments confirmed concept of the BLA design and showed remarkable agreement with computer modeling of the HOM energy absorption.

INTRODUCTION

The superconducting linac of the European XFEL facility [1] will deliver very short bunches of $\sigma_z = 25$ µm at maximum energy of 17 GeV to the insertion optical devices. Their nominal charge will be 1 nC and their intra-pulse rep. frequency will be 4.5 MHz. The nominal RF-pulse rep. rate is assumed to be 10 Hz. Frequency spectrum of the nominal beam will reach very high frequency in the THz range. The integrated longitudinal HOM loss factor of the TTF type cryomodule, housing eight 9-cell cavities, is 141 V/pC. The total deposited HOM power by the nominal beam (27000 bunches/s) will be 3.81 W, if no synchronous excitation will take place [2]. Its distribution for two frequency ranges, under- and above cut-off, is shown in Fig. 1. All modes below cut-off will be suppressed by coaxial HOM couplers [3] attached to each cavity. A big fraction (~85%) of the propagating power will be dissipated in the beam line absorbers. This will help to preserve the beam quality and to mitigate an additional cryogenic load at 4 K.

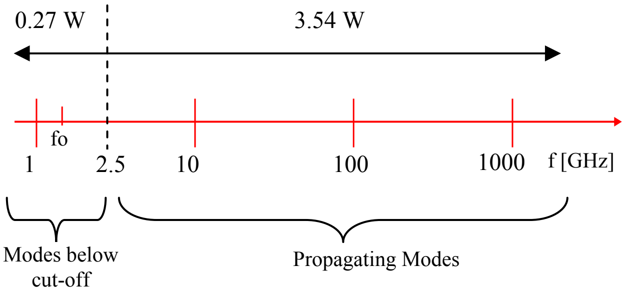

Figure 1: HOM power distribution for XFEL cryomodule vs. frequency for the nominal pulse operation.

BLA`s will be installed in all interconnections between cryomodules, and at the beginning and end of all linac subsections. In the absorber design we took 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 capacity has been specified to 100 W, which will allow for acceleration of up to one million nominal bunches/s.

BLA CONCEPT AND PROTOTYPE

The proposed layout of BLA is shown in Fig. 2 [5]. The absorber 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 absorption of propagating microwaves by the ceramic material was proven in the test carried out at the TTF linac in 2002 and reported later in [2]. The stub transfers dissipated energy to the 40-70 K cryostat shield via an external thermal connection. A stainless steel bellows serves as thermal barrier between the 70 K level and the 4 K cold vacuum chamber. Figure 3 shows parts of the BLA prototype before the assembly.

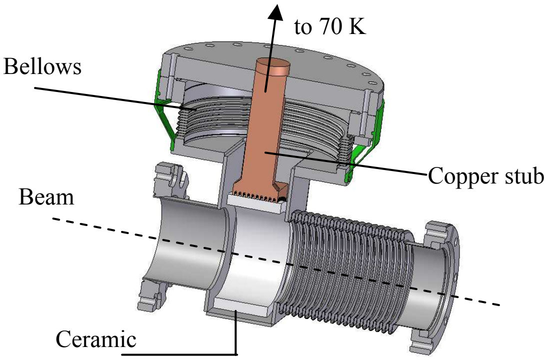

Figure 2: Layout of the beam line absorber.

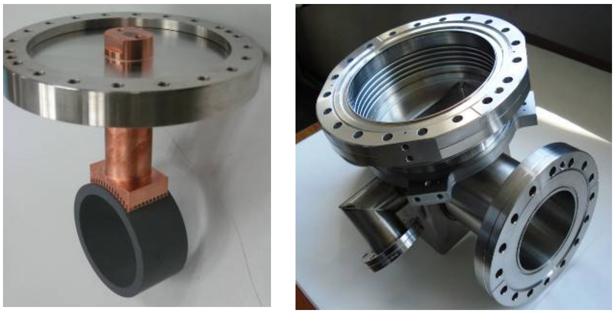

Figure 3: parts of the BLA prototype: (left) damping ceramic ring welded to the copper stub and (right) housing made of stainless-steel.

PREPARATION FOR BEAM TESTS

The first BLA prototype, built at DESY in 2006, was installed downstream, right after the cryomodule ACC6 in the accelerator of FLASH facility. The localization and photograph of the installed BLA is shown in Fig. 4.

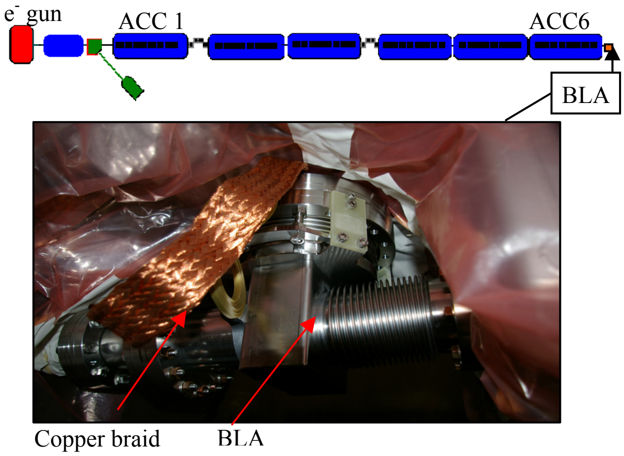

Figure 4: The BLA prototype installed in the TTF linac.

The copper stub of BLA has been connected to 42 K tube, cooling the outer thermal shielding in cryostats, with 70 cm long copper braid. The cross-section of braid was 74 mm^2. The thermal conductance of braid at 42 K was estimated to 0.13 W/K. We attached three thermometers to measure the heat flow in braid, two at the end on stub side and one at the end on the 42 K tube side. Monitoring the temperature at both ends of the braid allowed for estimation of the power dissipation in ceramic ring.

The absorption of propagating modes depends on periodicity of the BLA's positioning. The computer modeling showed that for the current prototype position only 15% of the HOM power, P_{hom}, generated by the beam in ACC6 will be absorbed by the ceramic ring.

BEAM TEST IN 2008

The first beam test took place in September 2008 after several weeks of preparation of the high beam current run of FLASH. In that experiment, the charge/bunch was up to 3 nC, number of bunch/pulse was up to 500 and the nominal bunch length σ_z was 1.5 mm. The HOM longitudinal loss factor for one cryomodule at this bunch length is 54 V/pC. The operation of FLASH linac was not very stable during the experiment, especially with high charge bunches. The monitored temperatures did not saturate, indicating that thermal effects in BLA were not stabilized due to rather short periods when the high current beam was on. An example of measured data is shown in Fig. 5. The beam induced HOM power and the temperature of two thermometers on the stub side increased and decreased synchronously. The maximum observed temperature rise of 1.1 K showed that up to 143 mW of heat was dissipated in the absorber. The computed absorbed power of 180 mW for the beam in that run is relatively close to the measured heat.

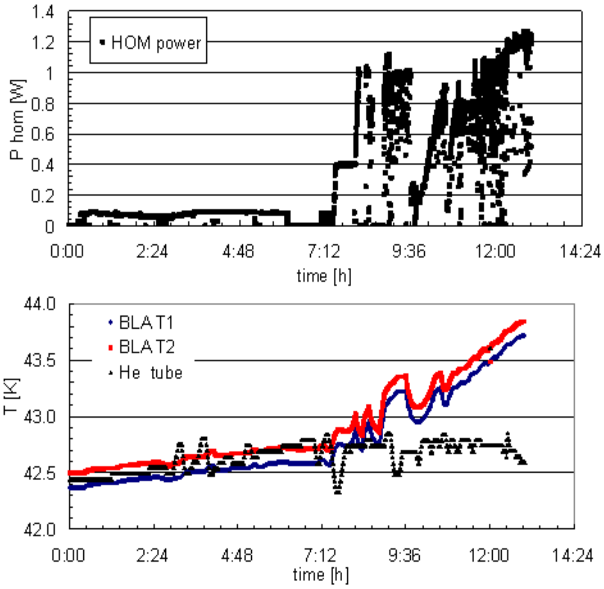

Figure 5: Power deposited in ACC6 (upper diagram) and corresponding temperature measured with the three thermometers (lower diagram).

BEAM TEST IN 2009

The second beam test, with more stable conditions, took place in September 2009. The charge/bunch was this time up to 3.2 nC and the nominal bunch length was as in the previous test 1.5 mm. The linac could be operated stably with 800 bunches/pulse. This time we observed saturation in the absorption process. An example of the induced HOM power in ACC6 and corresponding temperatures are shown in Fig. 6. In the presented here run (from 4 am till 8 am), the estimated mean HOM power in ACC6 was 1.7 W, which means that 255 mW shall be dissipated in the absorber. The maximum measured temperature rise of 2.5 K indicated absorption of 325 mW, which was this time higher than the computed value.

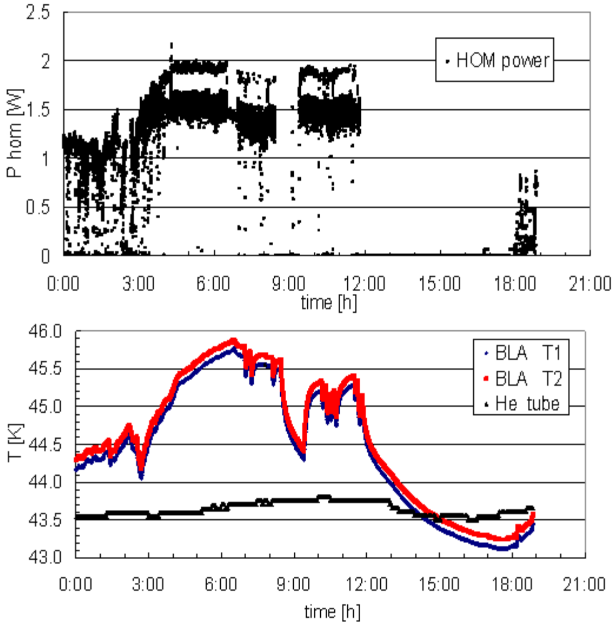

Figure 6: Power deposited in ACC6 (upper diagram) and corresponding temperature measured in 2009 (lower diagram).

Two beam tests, carried out in 2008 and 2009, proved the concept of beam line absorber we want to implement in the XFEL cold linac. For the XFEL accelerator we will need ~100 absorbers. The cost of the device plays an important role and the presented here design is significantly less expensive as compared to other proposed concepts. This is mainly due to replacing many damping tiles in other designs with one damping ceramic ring and only one brazing needed to hold the ceramic in the beam tube.

NEXT STEPS

Thermal Connection

The thermal connection of BLA to the He tube, which temperature can vary from 40 to 70 K, is not technically simple. For the XFEL nominal pulse operation, when the dissipation is 3.81 W, the connection can be made of a copper stub, terminated on each end with short braid, eliminating mechanical forces during the cool down and warm up cycles. The temperature distribution in thermal connection proposed for the nominal operation is shown in Fig. 7. The highest temperature at the ceramic ring is 59 K when the He tube is at 50 K.

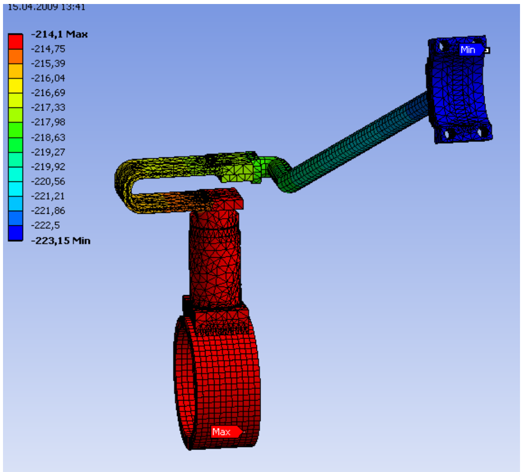

Figure 7: Temperature in the thermal connection to the He tube.

For the upgraded operation, when dissipation will by at least order of magnitude higher, presented connection is not suitable. The thermal modeling showed that already for 30 W dissipated HOM power the highest temperature on ceramic ring will increase to 230 K if proposed connection would be used. Higher conductivity connections, for example with an active helium gas cooling, are much more expensive and thus they will be implemented when the XFEL linac will be modified for the new operation mode.

Mechanical support

The weight of BLA is 21 kg. We will model the whole beam line section between cryomodules to estimate deformation of Al gaskets used to connect BLA to the beam line. In parallel, we are preparing an experiment to test long term mechanical deformations of that section resulting from the weight of BLA. In case the results of modeling and/or experiment will indicate a deformation leading to leakage we will use a mechanical support for the BLA to mitigate the forces on gaskets.

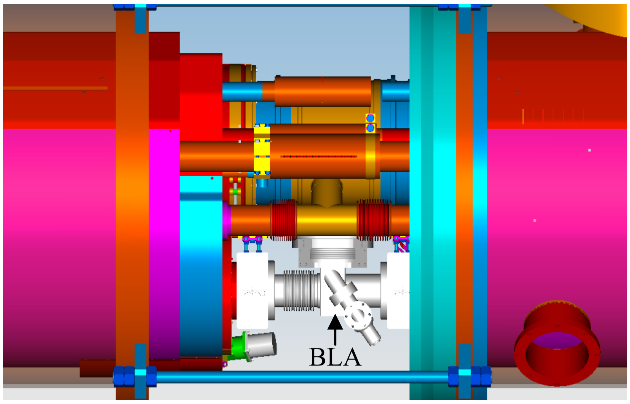

Figure 8: BLA installed between cryomodules.

Next Prototypes

All BLA's needed for the XFEL linac will be delivered as part of the in-kind contribution by INS-Swierk in Poland. Three BLA prototypes will be manufactured at INS-Swierk by the end of this year to establish the technology for the series production.

ACKNOWLEDGMENTS

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