BUTTON BPM DEVELOPMENT FOR THE EUROPEAN XFEL

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Abstract

Button beam position monitors will be the main BPM type used to measure the electron beam position at the European XFEL. Two different kinds of buttons are necessary: one type will be installed in the acceleration modules of the cold linac and the other in the warm environment. The electro-magnetic design of the feedthrough will be discussed. A comparison of the designed and measured RF properties will be presented. In addition to the usual RF properties, also the properties at cryogenic level will play a role for the BPMs in the cryo modules. HOM power must not heat up the BPM feedthroughs, in order to keep the cryo load of an overall accelerator module low, and also to prevent damage due to large temperature gradients over the ceramics of the feedthrough. First beam measurements at FLASH show good agreement of the RF properties with the expectation.

INTRODUCTION

The European XFEL is being build at Hamburg [1], host is DESY. The beam position in the over 3 km long linear machine needs to be controlled. This will mostly be done with button Beam Position Monitors (BPMs). At places with higher resolution requirements cavity BPM types will be used [2]. The accelerator consists of superconducting cavities grouped in cryo modules. To be able to control the beam position in these modules a BPM is included, that has to withstand the large temperature difference between 2 and 300 K (for maintenance). All button BPMs have to provide a resolution of better than 50 μm for the charge range 100 pC to 1 nC. A high signal level with special spectrum distribution is essential for the processing in the electronics, provided by the Paul-Scherrer-Institute [3]. In this contribution we will describe the properties of the cold and warm buttons and their feedthroughs.

COLD BUTTON

Electrical Properties

The beam tube diameter in the modules is 78 mm. For high signal amplitudes a large button diameter of 20 mm will be used (Fig. 1). To transfer the signal to the electronics a large gap of 3 mm between button and housing of the feedthrough can be applied. The wake loss factor of this BPM with 4 buttons results in 0.8 V/pC for a beam with 25 μm length. This is small enough to result in a negligible influence to the beam.

Figure 1: Photo of a cold copper button.

A prototype BPM is installed at the warm part of FLASH. The signal is transfered to a about 60 m long cable[1]. A measured spectrum is shown in Fig. 2 compared to a simulation result [4]. The simulation is using a much

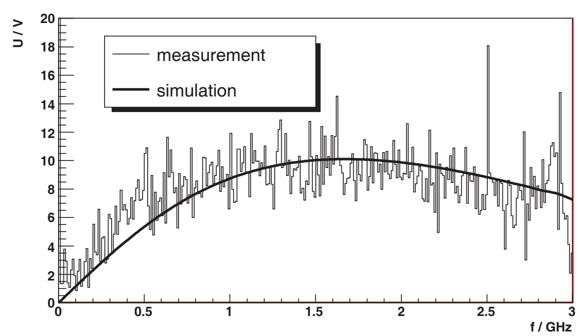

Figure 2: Measurement of the electrical spectrum from the button compared with a scaled simulation result [4].

longer beam length (20 mm) which suppresses higher frequencies and corresponds to the low-pass filter properties of the cable. The spectrum distribution of measurement and simulation agree to each other, especially a non-resonant distribution is requested which is essential for the electronics development, because it will base on broadband data processing up to about 2 GHz.

Mechanical and Thermal Properties

The installation of a button BPM in the cold modules requires special thermal properties. One is that the buttons will not induce a large power by itself to warm up the environment. Two power sources at the BPM are identified: the wake loss (see previous section) and the traveling higher order modes from the accelerator. The latter deposits power

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[1] At the European XFEL the maximum cable length between cold button and electronics will be 35 m.

on the button as a function of its surface resistance. Therefore copper was chosen as the surface of the button. At maximum beam load of the European XFEL (30 Hz repetition rate, 4.5 MHz bunch repetition, 1 nC) the loss at the BPM will be 78.7 mW (this is mostly due to the wake loss, because the copper resistance is low). In Fig. 3 the simulated temperature distribution at the BPM is shown. In

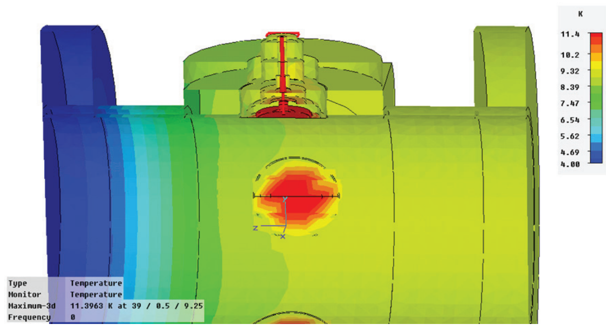

Figure 3: Temperature simulation [4] result of a copper button with highest power at the European XFEL.

the simulation a cooling is only applied at one side of the flange (in direction to the cold cavities), therefore this distribution shows the worst case. The highest temperature of 11.4 K is found on the button which is still low enough to not influence the environment temperature and keeps the mechanical stress on the feedthrough low.

Since there was no suited commercial feedthrough available, the design of the feedthrough was developed at DESY. Only non-magnetic materials are allowed for this component. One main design criterion was the operation safety at cryogenic temperature. This was checked by FEM simulations done by the company NOVICOS at Hamburg. The simulation of BPM and feedthrough covers thermo cycles between 4 K and room temperature, with following results:

- Due the temperature changes the button position varies by < 0.05 mm, see Fig. 4.
- The yield strength of the gasket is exceeded so that a permanent deformation of contact surfaces to the flanges is determined, see Fig. 5.
- Evaluation of the stress at the vacuum barrier of the inner pin, see Fig. 6.

Prototypes of this design have been ordered from different companies. The vacuum and cryogenic properties of the feedthroughs have been tested in a vertical cryostat. The test consists of 10 temperature cycles between 330 and 4 K. Duration of cool down and warm up was 30 min each. All 100 feedthrough are tested successfully.

The measured electrical BPM center depends on the position of the four buttons in the body. Extensive calculations and practical tests were done to optimize the assembly of the feedthrough flanges. The tightening torque and forces of the bolted connections as well as settlement of

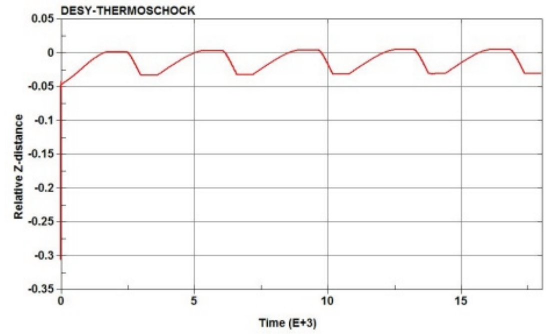

Figure 4: Position of the button in mm as a function of time. The thermo cycles are visible.

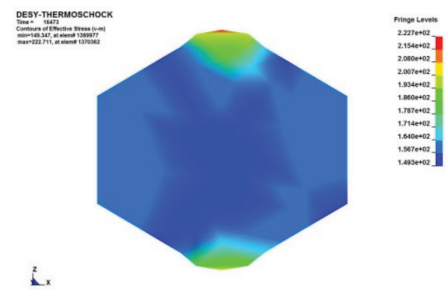

Figure 5: The deformation of the gasket cross section is shown. The contact is on top and bottom.

the aluminum gasket have been evaluated to guarantee a negligible small offset of the button electrodes. Additional complication is the requirement to assemble the BPMs in a cleanromm of ISO class 4. This requirement has influence on the friction forces of bolts and nuts, the combinations of materials and the methodical steps of the assembly. The tests have shown that an assembly with standard screws is not possible. The combination of titanium stubs and stainless steel nuts turned out to be suited. Based on the calculations tests were done to determine the torque for the feedthrough assembly to guarantee the correct position of the button.

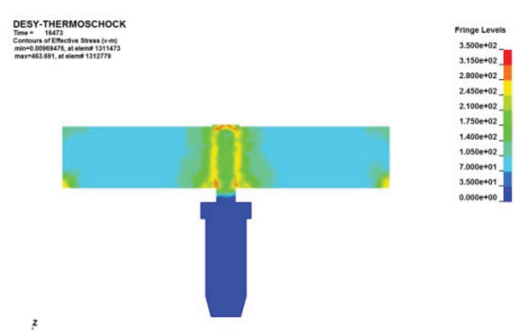

Figure 6: The stress of the inner pin at the vacuum barrier of the feedthrough.

WARM BUTTON

Electrical Properties

The standard beam pipe diameter at the European XFEL is 40.5 mm. This requires a second feedthrough type with a smaller button diameter: 16 mm. The feedthrough is designed to provide low loss, corresponding to low reflection. 40 prototypes have been produced, 5 of them with an N-connector replacing the button. This modification allows to measure the transmission and reflection, see Fig. 7. The

Figure 7: Photo of the warm button, with button (left) and with adapter (right).

measured reflection as a function of frequency is shown in Fig. 8. The requirement is < -25 dB up to 2.5 GHz,

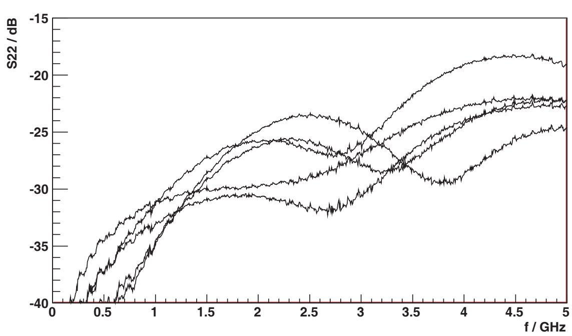

Figure 8: Measured reflection as a function of frequency of the warm button with adapter.

which is fulfilled by 4 of 5 modified feedthroughs. The reason that one feedthrough is slightly out of specification might be due imperfect matching of the N-connector to the feedthrough.

One BPM prototype is installed at FLASH with a cable of about 80 m length. A spectrum of the signal is shown in Fig. 9 compared with the simulation results. Again a longer beam is used in the simulation to take into account the low-pass filter of the cable. Both signals agree to each other. To measure the monitor constant the beam was moved by using a steerer and the position was controlled with a screen station nearby. The amplitudes at the vertical planes are calculated with the delta over sum method. The monitor constant is derived from this measurement to be 11.28 ±

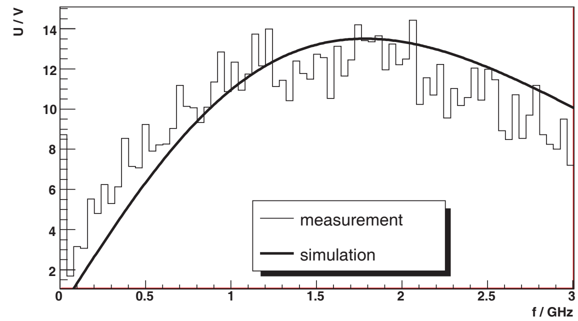

Figure 9: Measurement of the electrical spectrum from the warm button at 0.9 nC compared with a scaled simulation result [4].

0.72 mm which agrees with the simulation of 10.61 mm. Therefore this button can be used with the same electronics as those for the cold button BPMs. All results show, that this design is suited for the European XFEL standard warm button BPM.

Realization

A large number of warm button BPMs is required for the European XFEL. Besides of the RF parameters mechanical and vacuum properties, as well as the requirement of assembly and installation under cleanroom conditions (ISO 5) have to be fulfilled by the design. Furthermore the solution has to be cost effective due to the large number of items. Based on the HERA experience the mechanics was designed in collaboration with the company VACOM (Jena, Germany). The 40 prototypes mentioned before, have been produced in remarkable short time and with high quality.

SUMMARY

Button BPMs will be used at the European XFEL. A successful prototyping phase is almost finished. The cold feedthroughs fulfill the electrical and thermal requirements. The warm buttons were measured in laboratory and with beam and fulfill the requirements too. The signal from both BPMs can be processed with the same electronics.

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