BPMS FOR THE XFEL CRYO MODULE

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Abstract

The European XFEL is based on superconducting accelerator technology developed in the context of the TESLA collaboration [1]. The accelerator itself consists of cryo modules equipped with 8 acceleration cavities, followed by a quadrupole/steerer package, a BPM and a HOM absorber. This contribution will present the layout of the BPM system for the cryo modules, describing the monitor itself and its integration into the cryo module. Additionally, the electronics concept will be discussed. Finally the results of beam measurements at FLASH using prototypes of the monitor and the electronics will be presented.

INTRODUCTION

The accelerator complex of the European XFEL (Fig.1) at DESY will consist of a superconducting LINAC with a maximum energy of about 20 GeV. It is constructed out of 116 cryo-modules, with only a few warm sections intercepting the cold acceleration chain. The only monitor devices in the cold sections are the BPMs, one in each cryo module. They have to provide position and charge information along the LINAC.

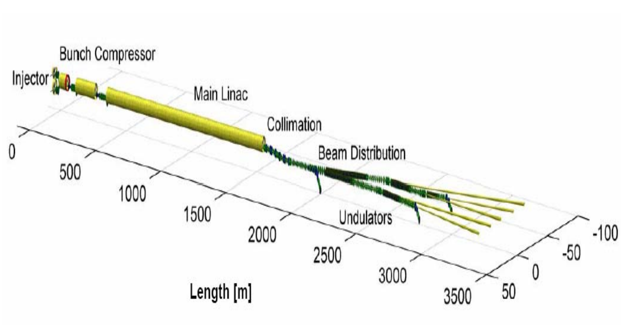

Figure 1: Scheme of the European XFEL.

In contrast to linear collider applications circular beam shapes are appropriate for FEL operation, relaxing the requirements on the XFEL BPMs compared to ILC specs [2]. The requirements on the XFEL module BPMs are listed in table 1.

Two BPM types are currently under investigation: a re-entrant cavity BPM developed by CEA, Saclay in collaboration with DESY, and a button type BPM. The latter is the topic of this paper. The status of the re-entrant cavity BPM is reported also on this DIPAC[3].

Table 1: Requirements of the BPM

Parameter	Value
Charge	0.1 – 1 nC
Bunch Spacing	200 ns (≥, arbitrary pattern)
Position Resolution	< 50 µm (Single Bunch)
Charge Resolution	1 %
Trigger	Internal/External (Gate)
Clock	100 MHz, Sync. To RF Master
Number of Bunches	3250 within 650 µs @ 30 Hz
Length	170 mm
Beam Pipe	78 mm
Align. Tolerance to magnetic Quad. Axis	300 µm, transversal 3 mrad, roll angle
Operation Temp.	4 – 20 °K

INTEGRATION INTO THE XFEL CRYO MODULE

The XFEL cryo module houses 8 TESLA cavities followed by a superconducting magnet block, consisting of a superferric quadrupole and a set of steerers. The BPM is mounted to the vessel of the magnet. Components to follow are a gate valve and the HOM absorber. Fig. 2 shows the layout of the end of the cryo module in detail.

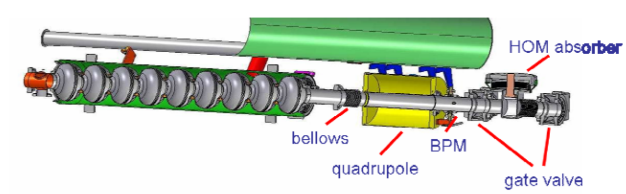

Figure. 2: Layout of the downstream end of the XFEL Cryo module.

In contrast to module BPMs at FLASH [4] (the former TTF), the BPMs are flanged and not welded to the beam pipe. The BPM has a length of 170 mm, with two fixed, (so) called "cavity flanges" on both sides. The beam pipe diameter is 78 mm. The inner beam pipe has to be copper plated. Since the BPM is connected to the liquid He vessel of the quadrupole, the BPM will be at a temperature close to the 4 K level. The vicinity of the superconducting cavities requires a particle free inner volume of the BPM (Cleanroom Class 10). The alignment to the magnetic axis and orientation of the quad has to be better than 300 µm (transverse) and 3 mrad (roll angle). The cables of the BPM have to be a compromise between low cryogenic losses and good RF properties.

BPM MECHANICS

Following the requirements on the mechanics inside the module a prototype pickup monitor has been designed. It is foreseen to mill the BPM out of a single piece of stainless steel, providing optimum tolerances and safety from the vacuum point of view. The alignment to the adjacent quadrupole will be based on field measurements of the quad and the use of dowel pins, included in the mechanical design of the BPM, in order to meet the tolerances mentioned before.

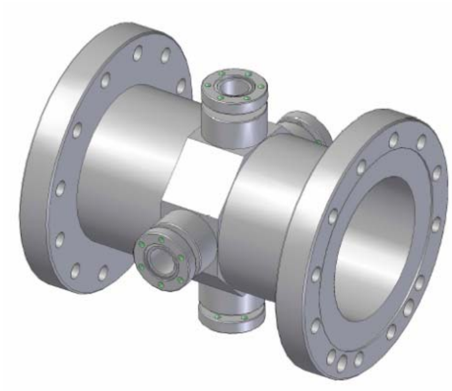

Figure 2: 3D Model of the BPM prototype.

The design of a prototype is shown in Fig. 2. In order to reach the required resolution at the lower charge limit of 0.1 nC, feedthrough geometries with a larger button size of 15 mm are currently under investigation for the final design. Therefore, there will be some changes concerning the mounting of the feedthroughs to the BPM body and concerning the feedthroughs themselves.

The feedthrough will be optimized for RF properties up to about 1.5 GHz. Another requirement is reliable operation in the cryogenic environment. Therefore, extensive tests are foreseen on a prototype series, but also all items of the series production will have to pass a cryogenic test.

Currently the design of a feedthrough is under investigation, starting from the version shown in Fig. 3. Some geometric properties will be optimized for a good compromise of RF and cleaning process.

Different material combinations, like stainless steel, titanium for body and pickup; molybdenum, CuBe or stainless steel for the inner conductor and alumina or glass ceramics for the insulator are currently under investigation. Also different assembly techniques like soldering or force fitting are evaluated. A study looking at the reliability in cryogenic environment with different feedthrough types, which were available at that time, has shown, that as well soldered as force fitted designs are suitable at low temperature [5].

Based on simulations signal amplitudes of 50 V_{pp} are expected for an electron beam of 1 nC passing the center of the button monitor. The RF response is expected to be flat in the frequency regime up to 10 Ghz (Fig. 4).

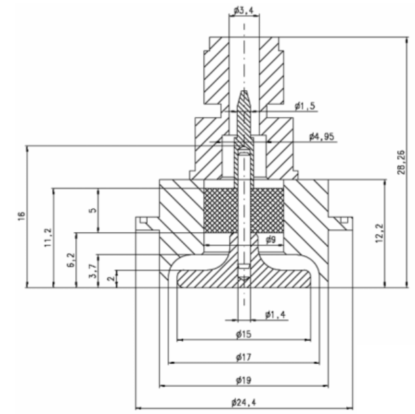

Figure 3: Design study for an XFEL feedthrough.

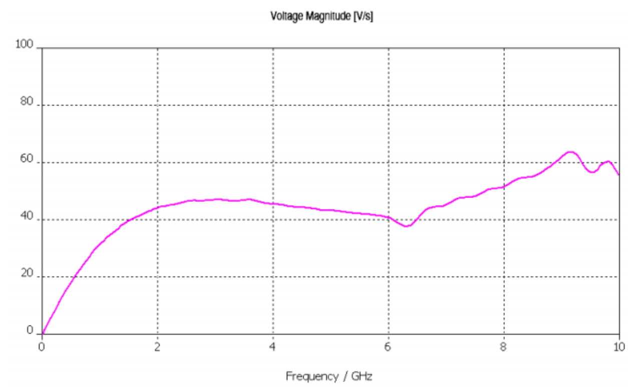

Figure 4: Signal output vs. frequency for a single button and 1 nC charge, simulated with CST particle studio.

ELECTRONICS CONCEPT

As mentioned in Table 1, the bunch to bunch distance in XFEL is as long as 200 ns. Furthermore, the requirement is a single bunch, single pass resolution of 50 µm. These requirements are close to the performance of the electronics type used for the DESY electron rings, typically operating with a bunch spacing of 96 ns [6]. Here the signals of the 4 buttons are added onto a single cable after running through delay lines of certain length. Thus the electronics gets a sequence of 4 pulses for processing. The amplitude of the incoming signals is digitized after peak detection. The influence of the delay lines is taken out by means of calibration. Due to the use of a single electronics channel, one gets good stability properties. XFEL will use a modified and updated version of this scheme. With the given orthogonal geometry of the XFEL BPMs it easy to separate the vertical and the horizontal plane and to process them by separate electronics. Thus there will be one electronic per plane. The electronics will provide both internal as well as external triggering. The external trigger will act more like a gate. The ADC is planned with a speed of 100 MHz, the clock has to be beam synchronized.

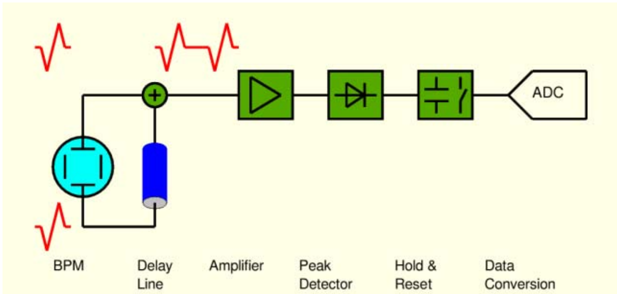

Figure 5: Block diagram of the BPM electronics for the pickup BPMs.

In order to deal with drifts of the delay line network a test and calibration facility will be included in each electronic. It will allow not only help with the commissioning of the system, it allows to send and analyse test pulses before or after each RF pulse of the LINAC, for testing and online calibration.

Since there will be various types of BPMs for XFEL this electronics has to be integrated into an overall framework of a BPM system. Currently this framework is under discussion with the colleges from PSI who plan to collaborate with XFEL on the warm BPM system. It is planned to integrate this electronics, including analogue front end to ADC as a piggy pack board to be mounted on a common processing board. The cold BPM electronics would appear like an ADC unit to the processing board.

Based on the test setups the layout of the PCB for a prototype series is under development, and the boards will be available for testing in summer 07.

BEAM RESULTS AT FLASH

A prototype of this XFEL BPM with adapted flange type (CF) and 8 mm buttons was installed in the FLASH LINAC.

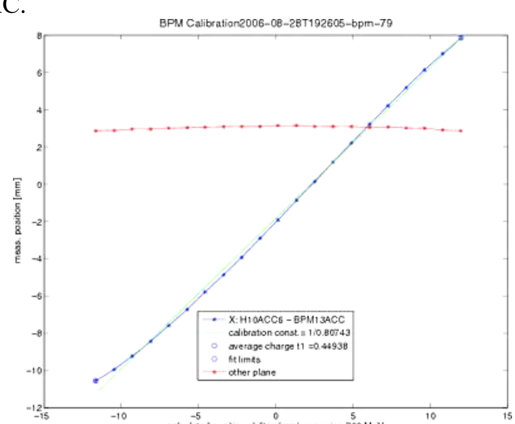

Figure 6: BPM response vs. an upstream corrector magnet at FLASH. The scaling of the x-axis corresponds to a displacement calculated from the kick of the magnet. The y-axis gives the reading of the BPM. The blue curve shows the hor. BPM reading, the red one the response of in the vertical plane. The slope of the fitted line gives the quotient between expected and measured BPM response.

Several studies have been performed with this monitor and different test setups for the electronics. The result of a measurement with this BPM and a first electronics prototype is in Fig. 6.

The BPM was included in resolution measurements using correlation techniques [7]. For different values of the charge in the range of 0.2 to 1 nC the resolution was measured to be better than 30 µm. Dynamic range of ±12 mm was also demonstrated, as well as the required charge resolution of 1%.

CONCLUSION

In this paper the design and first measurements of a prototype for the BPMs in the XFEL cryo modules are presented. With the current design for a button type monitor and an electronics based on the scheme used at HERA, the requirements for European XFEL can be met.

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