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INFLUENCE OF A BELLOW TO A CAVITY BPM FOR SINBAD

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Abstract

A cavity beam position monitor acts for the detection of the beam location within a pipe with high precision and best resolution. Some of them are used as a fixed point to refer the other parts of the beamline. To be able to fix the monitor against the other vacuum components bellows need to be adapted next to the monitor to relax the other part of the vacuum chamber. The bellow itself can create a resonance which would influence the resonator of the cavity beam position monitor. In this study the influence of the bellow to a cavity beam position monitor is investigated with simulations for a SINBAD project. The result is that the influence to the dipole resonator is below 0.1 %.

INTRODUCTION

SINBAD is a dedicated accelerator R&D facility currently under commissioning at DESY, Hamburg, and will host the ARES linac (Accelerator Research Experiment at SINBAD). It consists of a normal conducting photo-injector and a 100 MeV S-band linear accelerator with beam repetition rates between 10 and 50 Hz for the production of low charge beams (0.5–30 pC) with (sub-) fs duration and excellent arrival time stability [1–4]. For dedicated user experiments bunch charges up to 1000 pC are foreseen. At a bunch compressor a tube diameter of 40.5 mm is requested with high demand on the monitoring of the beam position. Therefore a cavity beam position monitor (CBPM) with best resolution is foreseen as the monitor, the design of the European XFEL will be used [5]. Bellows will be installed before and after the CBPM to relax the vacuum chamber. Such a bellow consists of blades which have a larger diameter of the vacuum tube and will create resonances which could influence the signalof the CBPM. Therefore the influence has to be investigated and if necessary be minimized.

SETUP

Bunch compressors are essential for the generation of short bunches with applications in e.g. colliders, free electron lasers and advanced accelerator concepts. The up-and-coming ARES accelerator located at SINBAD, DESY will support the formation of 100 MeV, pC, sub-fs electron bunches for Laser Wake Field Acceleration research and development [6]. The bunch compressor consists of four dipoles and two collimators. To monitor the beam properties a screen station and a CBPM will be installed. Since the compressor needs to be variable in the beam deflection a relative large beam pipe is requested. One version of the CBPMs of the European XFEL has a beam tube diameter of 40.5 mm which will be used for this bunch compressor at SINBAD too [5].

The CBPM consists of a reference and dipole resonator and is adapted from a design of SACLA [7]. The working resonance frequency of the monopole mode of the reference resonator and the dipole mode of the dipole resonator are tuned to the same value of 3.3 GHz. The first resonator is necessary to measure the amplitude from the monopole mode as a function of charge to normalize the signal from the second resonator and define the beam direction. The second resonator provides a signal generated by the dipole mode proportional to the beam offset; for this the dominant monopole mode of the dipole resonator needs to be reduced. This is done by waveguides or slots [8]. The setup is shown in Fig. 1. Here only the dipole resonator on the left side

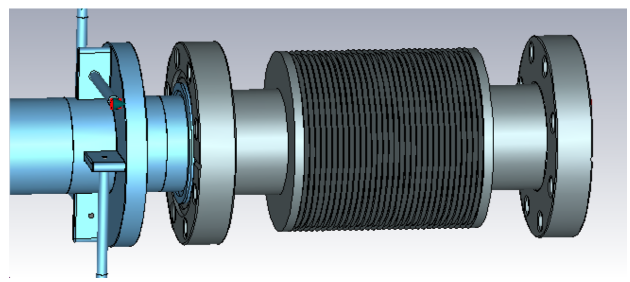

Figure 1: 3-dimensional simulation view of the vacuum part of the dipole resonator on the left in blue with the bellow on the right.

is shown and simulated with the simulation tool CST [9] because the reference resonator provides much higher amplitudes such that an influence from the bellow can be ignored. In Fig. 1 can be seen the dipole resonator vacuum view with slots and feedthroughs for the horizontal and vertical plane; a reversed reality view. The bellow is shown in normal view such that one can see the flanges and blades. Each blade forms a resonator which can induce resonances near the CBPM working frequency due to similar diameters and their amplitude can be enhanced because of the repetitive design. The field of the bellow resonances can be transmitted to the dipole resonator due to the relative large beam tube diameter but will be attenuated due to the distance between resonator and first blade of 73.7 mm.

SIMULATION OF THE INFLUENCE OF THE BELLOW

The tool CST provides beam simulations including wakefield generation which is capable to monitor the fields along the beamline. Resonances due to the beam propagation will be induced into the setup and can be visualized. Here voltage monitors are defined at the end of the feedthroughs from the slots to measure the responds of the beam at the exit of the CBPM. The simulation time of the beam propagation is defined until 18 ns which corresponds to the processing

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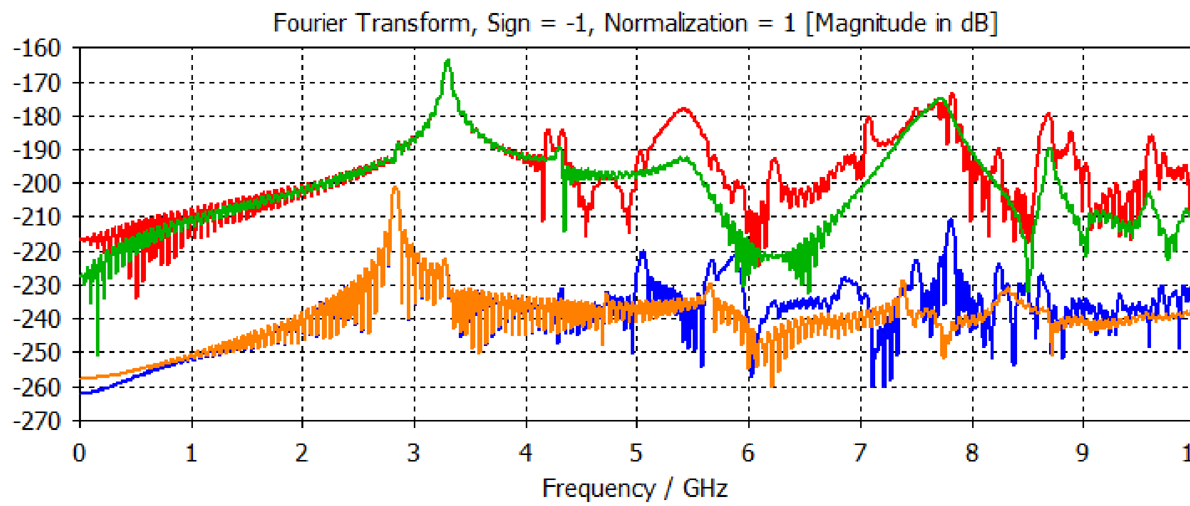

Figure 2: Signal spectrum measured at the exit of the CBPM dipole resonator with (red) and without (green) bellow at 1 mm beam offset. Similar spectrum is shown for the vertical plane without offset with (blue) and without (brown) bellow.

time of the used electronics: within this time window the peak of the down-converted signal in frequency domain will be measured in reality. The voltage monitors provides the voltages as a function of time and include all resonances in time domain which would enter the beginning of the cables, this will be visualized in frequency domain by a Fourier transformation. Settings of the simulations are: 1 nC beam charge, horizontal offset of 1 mm (to generate dipole and quadrupole modes) and centered in vertical direction; the wakefield solver is used with hexahedral mesh. A high number of mesh cells are used to reach a low resolution of the simulation results.

In Fig. 2 the Fourier transformed signals on the horizontal and vertical CBPM exits with and without bellow are shown. The green line provides the signal without bellow and 1 mm offset; this one shows the dominant dipole resonance at 3.3 GHz. Similar amplitude for the case with bellow is shown with the red line. At lower frequencies the uncertainty of the case with bellow is larger due to the larger amplitude variations but is still within the trend. At 2.8 GHz a small resonance is visible for the horizontal plane; this corresponds to the transmission of the monopole mode of the dipole resonator which is already negligible compared to the dipole mode and is reduced by the slot. This is a prove that the slots reduce the monopole mode, compare with [8].

For the horizontal case the red line with bellow shows higher amplitudes for several higher frequencies, for example 4.2 GHz, 4.3 GHz, 5.4 GHz, 6.2 GHz and so on. These resonances are generated in the bellow and transmitted until the feedthrough exit of the dipole resonator. Other frequencies can be generated too but will not be monitored due to the position of the voltage monitor. But these other not visible resonances are of no concern since they will not be transmitted to the electronics.

The voltage amplitudes in the vertical plane are shown in Fig. 2 too: with (blue) and without (brown) bellow. At the dipole resonance frequency of 3.3 GHz the vertical plane shows a reduction of the amplitude by lower than -60 dB which corresponds to the orthogonal de-coupling of the resonator [10]. The resonance of 2.8 GHz is the monopole mode of the dipole resonator, the amplitude is below the case with offset. For higher frequencies additional resonances compared with the horizontal plane are visible which are generated and transmitted to the vertical feedthrough at 5 GHz, 5.7 GHz, 5.9 GHz and so on.

Important for the influence of the signals are the amplitude change due to the bellow with offset. In this case the horizontal plane is used because in the vertical plane with centered beam shows no amplitude at the working frequency. The amplitudes are compared at the dipole resonance of 3.3 GHz with and without bellow within the bandwidth of the electronics of about 50 MHz. In this case the amplitude in frequency domain increases by 0.06 % with bellow which is negligible small. Therefore this influence for the CBPM signal processing can be ignored.

Higher order modes are visible and transmitted to the exit of the CBPM into the cables. These indicate that modes are generated and transmitted, other not transmitted modes which are not visible from these voltage monitor positions can be generated too but are of no importance for the CBPM functionality. Therefore this method is useful to prove the influence of the bellow to the CBPM. But higher modes are existing and could transmit to other components and their influence have to be proven as well.

SUMMARY

A CBPM will be installed in the bunch compressor of SINBAD. To relax the mechanics of the vacuum tube bellows will be attached on each side. The influence of additional induced fields due to the beam in the system CBPM and bellow are simulated and found to be negligible because at the working frequency of the electronics the change of amplitude is small. Higher order modes are visible too but

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are outside of the working frequency of the used electronics. This is proven with beam simulations without monitoring all resonances separately by using the wakefield solver. This provides a general method to prove the influence.

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