REALIZATION AND MEASUREMENTS OF CONE-SHAPED PICKUPS FOR BUNCH ARRIVAL-TIME MONITORS FOR FLASH AND XFEL*

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Abstract

At the Free Electron Laser FLASH at DESY, the state of the art Bunch Arrival-time Monitors (BAMs) have a time resolution better than 10 fs for bunch charges of more than 500 pC [1]. With the extension of FLASH II and the European X-ray Free Electron Laser Project (XFEL) a low charge operation mode with 20 pC bunch charge is planned. The time resolution of the BAMs significantly drops as the bunch charge reduces [2]. High bandwidth BAMs are essential for a femto-second time resolution of the measured arrival-time in case of low charge and high charge operation mode of the free-electron lasers (FELs). The proposed cone-shaped pickup electrodes with bandwidth up to 40 GHz are manufactured and measured. Due to the different beam pipe apertures for FLASH and XFEL, two hermetic bodies are manufactured. The RF properties of the pickups are measured and compared to the simulation results obtained by CST MICROWAVE STUDIO®.

INTRODUCTION

For providing an optimal operation of the free-electron lasers (FELs), which generate ultra short X-ray pulses, the arrival-time of the electron bunches has to be measured with femtosecond precision. For that purpose Bunch Arrival-time Monitors (BAMs) are developed and installed at the Free Electron Laser FLASH at DESY. These arrival-time monitors combine the beam induced signal with an electro-optical detection scheme as described in [1]. The time resolution of such a detection scheme depends on the steepness of the pickup voltage slope at the first zero-crossing. The state of the art BAMs have an intrinsic time resolution better than 10 fs for bunch charges of more than 500 pC [1]. With the extension of FLASH II and the XFEL, a low charge operation mode with bunch charge of 20 pC is planned. The slope steepness reduces with lower bunch charges leading to significant performance degradations [2]. This can be compensated by increasing the bandwidth of the BAM components. The BAMs comprise RF-pickups, an electro-optical front-end and read-out electronics [3].

In this paper we present the realization and the measurements of cone-shaped pickups for the BAMs with bandwidth up to 40 GHz proposed in [4]. The pickups are characterized by scattering parameters and the results are compared to the simulations performed with CST MICROWAVE STUDIO®.

HIGH BANDWIDTH CONE-SHAPED PICKUPS FOR BAM

In order to achieve sub-10 fs time resolution for bunch charges of 20 pC or lower, the bandwidth of the BAM pickups should be increased up to 40 GHz. With this bandwidth the voltage slope at the first zero crossing of the pickup signal is more than 300 mV/ps at 20 pC [6].

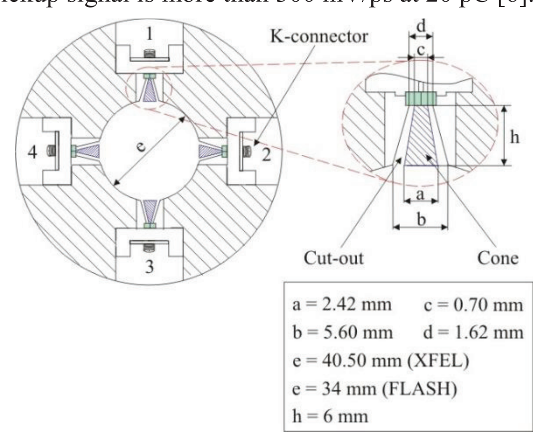

Figure 1: Cross-section of the cone-shaped pickups with the denoted ports.

Figure 1 shows the cross-section of the high bandwidth cone-shaped pickups. The design details can be found in [4 - 6]. Eight pickups have been produced by Orient Microwave Corp [7]. The pickups are mounted in the stainless steel hermetic body. Due to the different beam pipe apertures for FLASH and XFEL, two hermetic

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bodies are produced with flanges CF63 and CF50 respectively. Figure 2 shows a single pickup (top and side view) and the pickups mounted in the hermetic body.

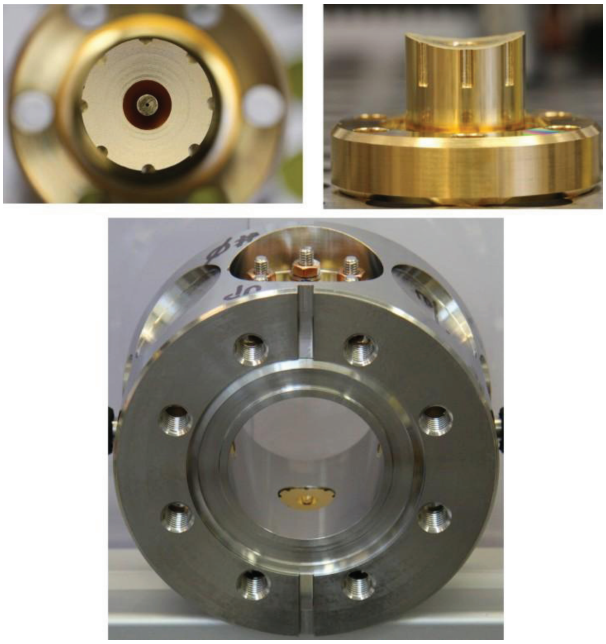

Figure 2: Top view of the pickup (top left) and side view (top right) . Pickups mounted in hermetic body (bottom).

During the production process of the hermetic body, the thickness of the copper gasket was not taken into consideration. This prevents the pickup to be in the vicinity of the beam pipe aperture and creates a step (0.5 mm) from the beam pipe to the pickup (Fig. 3).

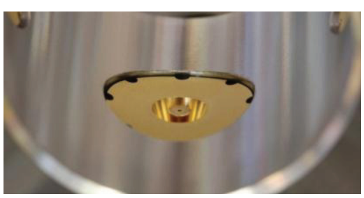

Figure 3: Pickup mounted in the body with a step to the beam pipe.

The step creates an impedance jump and influence the RF properties of the device. The simulation results in Figure 4 show the effect of the gap on the beam induced signal. The output signal strength is reduced by 5 dB.

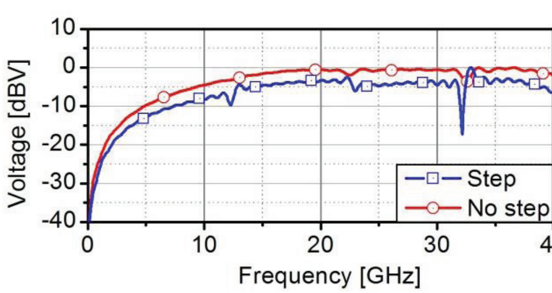

Figure 4: Comparison of the spectrum of the pickup voltage signal with step and no step transition to the beam pipe.

The resonance at 32 GHz contributes to the ringing of the voltage signal.

MEASUREMENT OF THE PICKUPS

For characterizing the pickups and validating the simulation results several measurements are performed with a Vector Network Analyzer up to 40 GHz. At first, the pickups shown in Fig. 2 (top left/right) are measured in free space. The reflection coefficients (S_{11}) obtained from the eight pickups was compared to a reference one and the relative error was calculated. Figure 5 shows the obtained results.

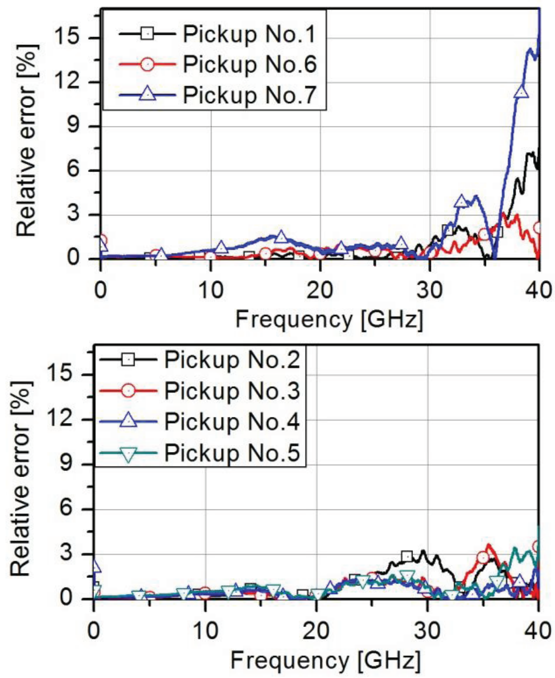

Figure 5: Relative error of the reflection parameters of the pickup compared to pickup No. 0.

The pickups are enumerated from 0 to 7. The pickup marked as pickup No.0 was taken as a reference. From the plots one can see that the pickup Nr. 7 has the largest difference in the reflection (up to 16% at 40 GHz) compared to the other pickups. It is anticipated that the deviations result from the different manufacturing tolerances of this pickup. However, up to 35 GHz the pickup has deviation less than 5%. The other pickups (except pickup Nr. 1) have deviation less than 4% in the entire frequency range up to 40 GHz. This is sufficient for delivering a symmetric pickup signal at the output. After the mounting of the pickups in the hermetic bodies, the cross-talk between the pickups is measured with open body in free space. The results obtained from the measurements are compared to the simulation performed with CST MICROWAVE STUDIO®. Figure 6 shows the measurement and the simulation of cross-talk for the XFEL body.

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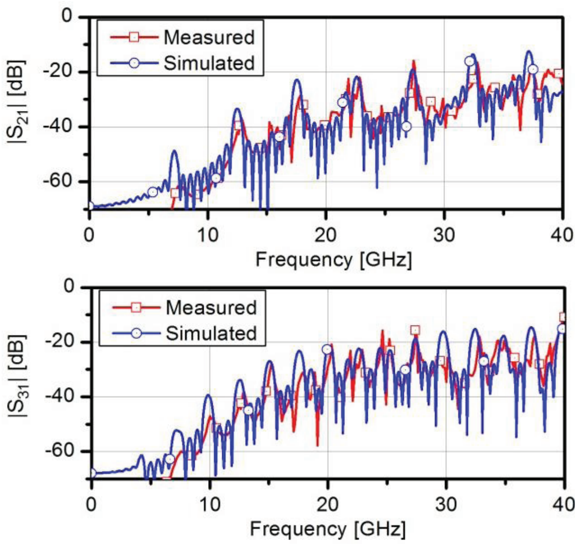

Figure 6: Simulation and measurement of the cross-talk for the XFEL hermetic body.

There is a relatively good agreement between the measurements and the simulation in the position of the resonant peaks. The level of the peaks and the Q factor is different due to the different losses in the simulated and the measured body as well as the relatively low resolution of the simulation. The big dimensions of the structure as well as the wide frequency range require very big computational power for high resolution simulation.

The cross-talk between the ports (see Fig. 1) is below -18 dB. As presented in [5], this minimizes the contribution of the cross-talk signal to the ringing. Figure 5 shows the measurement and simulation of the cross-talk for the FLASH body. From the S_{31} plot (Fig. 7 (bottom)) one can see that not all the peaks of the measurement fit with the simulation. The calibration uncertainties and relatively low simulation resolution can explain this behavior. Further investigations are in progress.

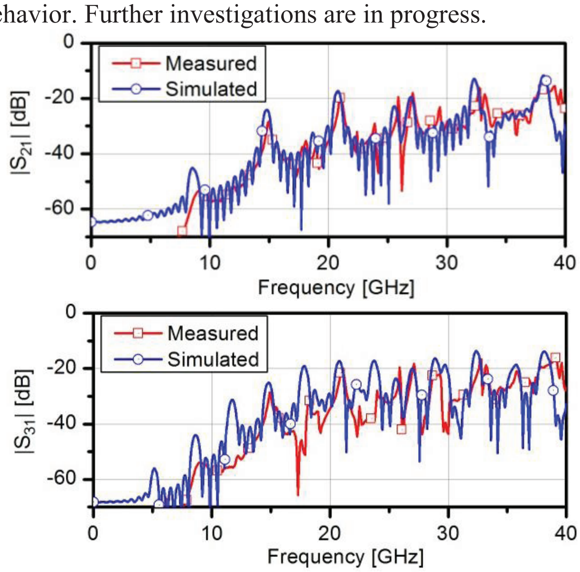

Figure 7: Simulation and measurement of the cross-talk for the FLASH hermetic body.

CONCLUSION

In this paper we have presented the realization and the measurements of cone-shaped pickup electrodes for the BAMs for FLASH and XFEL. The manufactured pickups are characterized with S-parameters and the results are compared to the simulations. From the relative error analysis we can conclude that two of the eight pickups show deviations in the reflection coefficient. The other pickups have deviations in the reflection less than 4%. The measured cross-talk for both bodies is below -18 dB. There is a good agreement between measurement and simulation for the pickups mounted in the XFEL body. For the FLASH body pickups one can see that some of the measured resonant peaks (S_{31} in Fig. 7) do not fit to the resonant peaks obtained from the simulation. However, the trend of the measured curve corresponds to the simulation. The step between the pickups and the beam line introduced during the mounting influences the output signal strength (reduced for -5 dB compared to the case with no step). The resonance effect at 32 GHz influence the ringing of the output signal. In the future implementation the step should be avoided in order to maximize the output signal with reduced ringing.

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