REALIZATION OF A HIGH BANDWIDTH BUNCH ARRIVAL-TIME MONITOR WITH CONE-SHAPED PICKUP ELECTRODES FOR FLASH AND XFEL*

A. Angelovski#, M. Hansli, A. Penirschke, R. Jakoby, Institut für Mikrowellentechnik und Photonik, TU Darmstadt, Darmstadt, Germany
A. Kuhl, S. Schnepp, Graduate School Computational Engineering , TU Darmstadt, Darmstadt, Germany
T. Weiland, Institut für Theorie Elektromagnetischer Felder, TU Darmstadt, Darmstadt, Germany
H. Schlarb, M. Bousonville, DESY, Hamburg, Germany

Abstract

In the Free Electron Laser in Hamburg (FLASH), an electro-optical system is used as a Bunch Arrival time Monitor (BAM). The time-of-arrival resolution is proportional to the steepness of the beam pick-up signal at the first zero-crossing. Future experiments will be conducted using significantly lower bunch charges resulting in reduced signal steepness. This requires BAM pickup electrodes with increased bandwidth. This paper presents the realization and measurement results of a high bandwidth cone-shaped pickup system capable of operating in the frequency range up to 40 GHz. The RF-measurements have been performed using a non-hermetic prototype of the BAM pickups for assessing the influence of manufacturing tolerances on the sensor performance.

INTRODUCTION

In order to achieve femtosecond stability in the synchronization process at the Free Electron Laser in Hamburg (FLASH), a Bunch Arrival-time Monitor (BAM) is developed as part of the electro-optical detection system described in [1]. The principle of measuring the bunch arrival-time is presented in [1]. The BAM comprises an RF-pickup, an electro-optical front-end and read-out electronics [2].

The resolution of the BAM is determined by the slope steepness at the zero crossing of the pickup signal [3]. The slope steepness depends on the peak-to-peak voltage and the duration of the voltage response. These two parameters are related to the geometrical parameters of the structure such as the diameter of the cone-shaped pickup or the diameter of the cut-out (see Figure 1). The changes in the geometrical parameters of the pickup components will influence the RF characteristics of the device as well as the performance of the system.

Through measurements we investigated the influence of changes in the geometrical parameter caused by the fabrication tolerances on the S-parameters.

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angelovski@imp.tu-darmstadt.de

CONE-SHAPED PICKUP DESIGN AND FABRICATION

In [4] a cone-shaped pickup was introduced. It was shown that the BAM pickup system has a slope at the zero crossing of approximately 382 mV/ps and operates in the frequency range of DC - 40 GHz. Figure 1 shows a sketch of the cross-section of the cone-shape pickup.

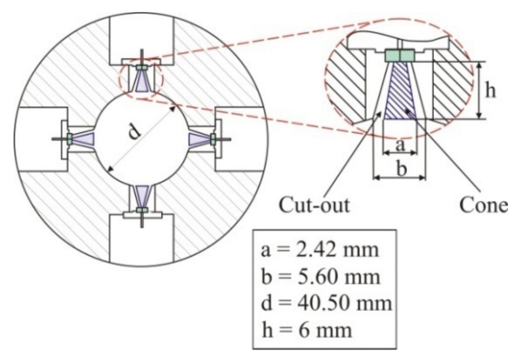

Figure 1: Cross-section of the cone-shaped pickup

The cone represents a continuous transition from the button to the pin of the connector. For maximizing the signal transmission, the pickup is matched to 50 Ω which means the ratio *b/a* is constant within the entire cone length with a value of 2.3. The dimensions of the prototype deviate from the original design presented in [4] which is due to manufacturing limitations in terms of equipment and tools. However, the matching requirements are still satisfied because the ratio *b/a* is kept. The diameter of the lower basis of the cone is a = 1.87 mm and of the cut-out b = 4.42 mm. The length of the cone is h = 4.1 mm, and the aperture of the flange is d = 42 mm.

A. Non-hermetic prototype

In order to investigate the impact of fabrication tolerances on the RF characteristics, a non-hermetic prototype of the cone-shaped pickup was built, which is shown in Figure 2.

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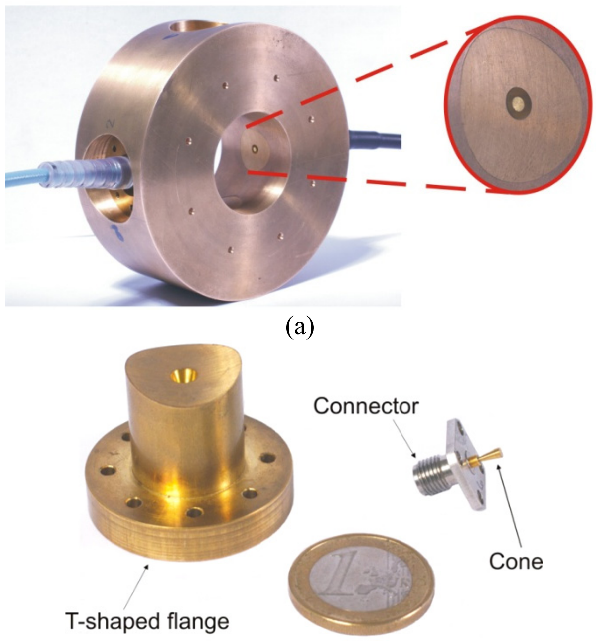

Figure 2: a): Photo of the non-hermetic cone-shaped pickup, b): T-shaped flange, the cone with the glass bead and the connector.

The entire structure is made of brass. We have used commercially available glass beads - K100B from Advanced Technology Group, Inc. for manufacturing Anritsu 2.92 mm K-connectors. The cone was soldered to the contact pin of the glass bead and positioned in the center of the cut-out of the T-shaped flange that follows the shape of the beam line. It has a tapered cut-out and holds the glass bead fixed and centered. All four T-shaped flanges are mounted into the disk flange. This modular design provides flexibility to change any of the four pickups in case of damage, off-center position or making upgrades and improvements without changing the entire pickup flange.

B. Measurements and validation

Manufacturing tolerances are intrinsic to the fabrication process. In order to assess the influence of these tolerances we have made a series of RF measurements of the prototype. Since the pickup system is symmetric, in the ideal case all of the measured values should be identical. For that purpose the reflection coefficient at each of the ports was measured and then compared.

The measurements of the pickup system were done with a Vector Network Analyzer. Figure 3 shows the reflection measured on each of the ports.

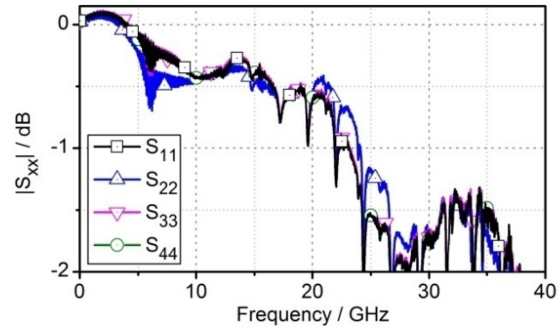

Figure 3: Reflection coefficients measured at the connectors.

From the plots we can see that the reflection at the ports is relatively high. This is due to the fact that the pickup cone is matched to 50 Ω to the connector, but miss-matched to the beam pipe in order to have loose coupling. The matching at the connector is necessary in order to prevent reflections of the pickup signal at the glass bead.

The reflection coefficient curves are in a good arrangement, except for port two that deviates from the other curves in the frequency range from 5 to 10 GHz and from 20 to 30 GHz. The maximum deviation is 0.4 dB. The cause of this deviation is being investigated.

The distance of the resonant peaks is approximately 3.5 GHz, which correspond to twice the distance between the ports, approximately 84 mm. One can also notice that the curves are slightly above zero in the beginning of the plot, which is due to calibration uncertainties.

By examining the pickup and measuring the dimensions of the cones, the cut-outs and the positions of the pickups, we noticed that the lower basis of the cone at port two is smaller compared to the others. The measured geometrical parameters are given in Table 1.

Table 1: Measured values for the diameter of lower basis of the cone

Port number	1	2	3	4
a **(mm)**	1.87	1.81	1.86	1.87

Due to the different diameter of the lower basis of the cone, the impedance of the coaxial tapered structure (cone and cut-out) is no longer matched to 50 Ω. The active surface of the cone is changed which leads to different coupling. That causes a change in the reflection coefficient.

In order to assess the influence of the cone dimensions over the reflection coefficient, we have disassembled the sensor and exchanged the cones between the port two and port three. The cone that was connected to port two is now removed and connected to port three, and vice versa. Then the measurement procedure was repeated. Figure 4 shows the obtained result.

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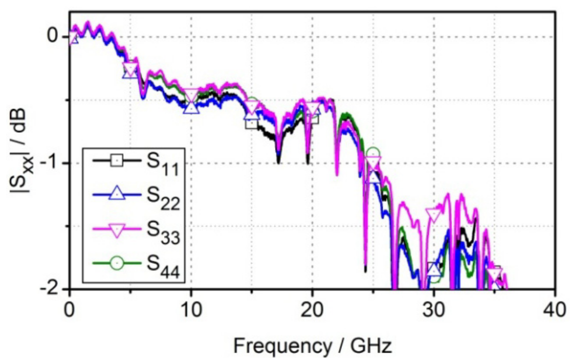

Figure 4: Reflection coefficients measured at the connectors with exchanged cones between port two and port three.

In Figure 4 one can see slightly different behaviour of the curves. There is a small deviation in the curves in the range from 5 to 15 GHz which may come from the disassembling and assembling process that was done for changing the cones and measuring the dimensions of the components. One can notice that the curve from the reflection coefficient S_{33} has highest deviations compared to the others, similar like the one from the curve S_{22} in Figure 3 with a value of approximately 0.4 dB. The deviation is in the frequency range from 26 to 35 GHz. From this result we can see that the cone with smaller diameter that was previously at port two, and then at port three, creates a deviation in the reflection coefficient. However, with the modular design one must be very careful during the assembling and disassembling process, in order to preserve the symmetric construction of the pickup system.

The cross-talking, or the transmission coefficient, is also an important parameter. The ringing of the pickup signal is connected with the cross-talking between the ports. When the isolation between the neighbouring ports is low we can notice attenuated but visible replicas of the signal itself shifted in time that corresponds to the distance between the ports. Figure 5 shows the measurements compared to the CST Microwave Studio simulation.

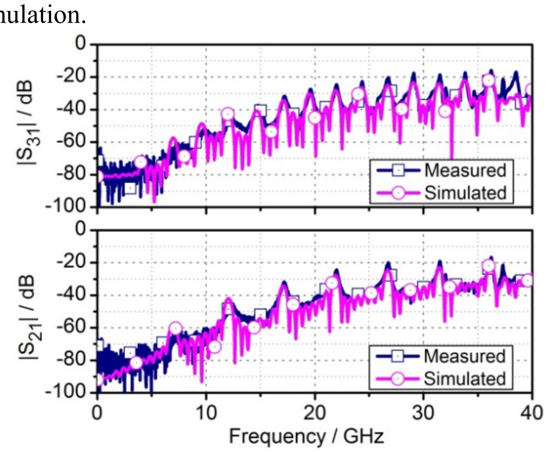

Figure 5: Cross-talking, measured vs. simulated.

From the plots one can see that the measured values are in a good arrangement with the simulated ones. The peaks correspond to twice the distance between the ports. The highest level of the cross-talking between the ports is around -18 dB in the range of 25 to 40 GHz. With this level of the cross-talking, the ringing amplitude in the pickup signal is less than 1% after 0.5 ns [4].

CONCLUSION

In this paper, a realization of cone-shaped pickup electrodes for a BAM is presented. A non-hermetic prototype was fabricated and the influence of the fabrication tolerances on the S-parameters was investigated. In an ideal symmetrical BAM pickup system, all of the measured ports should have identical characteristics. From the measurement of the reflection coefficient a deviation was observed in one of the ports. This deviation was investigated and we came to the conclusion that it is due to the smaller diameter of the lower base of one cone. The coupling to the beam depends on this parameter, and fabrication tolerance should be in the range of 10 μm in order to avoid strong influence over the system performance. Further investigations are in progress in order to assess the influence of the other geometrical parameters on the RF performance of the BAM pickup system.

The simulated and the measured values for the cross-talking are in a good arrangement. The maximum value of the cross-talking between the ports is around -18 dB, which attenuates the ringing in the pickup signal to below 1% of the peak amplitude after 0.5 ns, as presented in [4].

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