PICKUP SIGNAL IMPROVEMENT FOR HIGH BANDWIDTH BAMS FOR FLASH AND EUROPEAN - XFEL*

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Abstract

In order to measure the arrival time of the electron bunches in low (20 pC) and high (1 nC) charge operation mode, new high bandwidth pickups were developed as a part of the Bunch Arrival-time Monitors (BAMs) for FLASH at DESY [1]. The pickup signal is transported via radiation resistant coaxial cables to the electro-optic modulator (EOM) [2]. Due to the high losses of the 40 GHz RF frontend the signal in the RF path is attenuated well below the optimal operation voltage of the EOM. To improve the overall performance, the signal strength of the induced pickup signal needs to be increased and at the same time the losses in the RF frontend significantly reduced. In this paper, the analysis towards improving the induced pickup signal strength is presented. Simulations are performed with the CST STUDIO SUITE® package and the results are compared with the state of the art high bandwidth pickups. A non-hermetic demonstrator is built and the measurement results are compared with the simulation.

INTRODUCTION

The Bunch Arrival-time Monitor (BAM) at FLASH comprises pickup electrodes, electro-optical frontend and RF frontend. It utilizes an electro-optical detection scheme in combination with a beam induced pickup signal [3]. The bipolar pickup signal modulates an external laser pulse train by means of Mach-Zender type EOM. For determining the relative timing, the pickup signal is sampled at the first zero-crossing by one of the laser pulses. An amplitude modulation of the laser pulse occurs at the EOM when the arrival-time of the bunch is changed compared to the relative one. The arrival-time is determined by comparing the amplitude of the modulated laser pulse to the adjacent ones. The measured intrinsic time resolution with these scheme is better than 10 fs for bunch charges above 500 pC [3].

With the extension of FLASH II and the European - XFEL a low charge operation mode is planned with bunch charge of 20 pC. It was shown in [4] that the time resolution does not depend on the bunch charge higher than 200 pC but decreases significantly when it drops below 150 pC. In order to increase the time resolution for lower charges the bandwidth of the BAMs is increased from the current 10 GHz to 40 GHz [1, 2, 5].

As the bunch charge reduces, the induced voltage level in the pickup reduces as well. The introduced cone-shaped pickups in [1] have a peak-to-peak voltage (V_{pp}) of 2.6 V for bunch charge of 20 pC. For a high frequency signal, the losses in the RF path are high and the pickup signal is attenuated well below the optimal operation voltage of the EOMs [6]. The first measurements of the voltage signal at the end of the RF frontend showed a V_{pp} of 1.09 V [7].

In this paper we present an improvement of the cone-shaped pickups towards higher V_{pp} while maintaining the operational bandwidth of 40 GHz and a slope at the first zero-crossing higher than 300 mV/ps.

CONE-SHAPED PICKUPS FOR HIGH PEAK-TO-PEAK VOLTAGE

The beam induced pickup signal at the input of the EOM depends on the bunch, the pickup and the RF frontend. For given bunch characteristics (charge, length) the pickup signal bandwidth and the V_{pp} can be adjusted by tuning the pickup and/or the RF frontend properties. For increasing the V_{pp} of the signal, the active surface (cone diameter) of the pickup needs to be increased in order to have stronger coupling to the beam [8]. A comparison between the a cone-shaped pickup for FLASH and a modified cone-shape pickup with increased active surface is shown in Fig. 1.

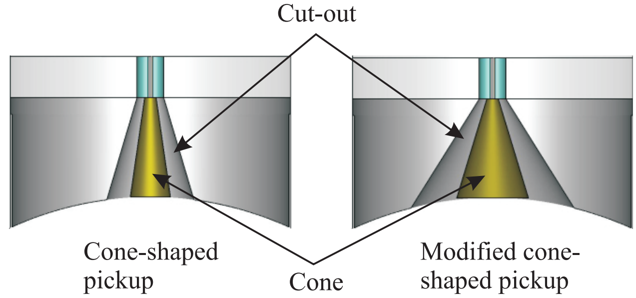

Figure 1: Cross section of the cone-shaped pickup (left) and the modified cone-shaped pickup for high peak-to-peak voltage (right).

However, the 50 Ω geometry needs to be maintained and the ratio between the outer conductor (the cut-out) and the

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inner conductor (the cone) should be 2.3 in vacuum (see Table 1).

The increase of the active surface is limited by the mechanical and the RF factors. The mechanical tension at the connection point between the cone and the glass bead connector with a diameter of 0.3 mm can become critical due to the increased weight of the cone and might lead to an unstable connection between them. This is currently under investigation. The dimensions of the beam pipe are a limiting factor as well.

As it is shown in [8, 9] the amplitude of the pickup signal is proportional to the error function of the diameter of the pickup. When the length of the pickup diameter is comparable to a few bunch lengths, the pickup voltage reaches the maximum. Further increasing of the diameter will not change the peak voltage level. Instead it will start decreasing when the cut-out opening will become resonant at the operating frequency of 40 GHz.

The V_{pp} can be further increased if the cone is slightly longer than the cut-out. However, this increases the inductance and in an extreme case the pickup signal loses the bipolar and obtains a Gaussian shape.

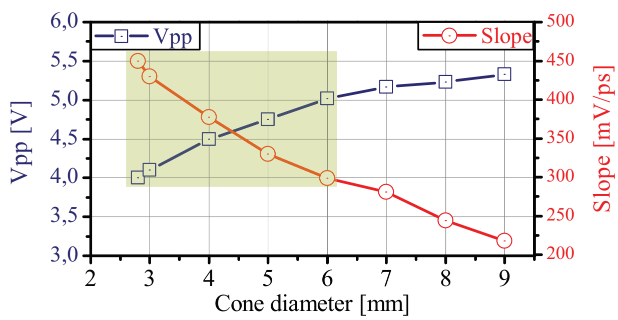

Figure 2: V_{pp} and the slope at the first zero-crossing as a function of the cone diameter. The optimum area is shaded.

Figure 2 shows the V_{pp} and the slope at the first zero-crossing obtained with a CST PARTICLE STUDIO® simulation of the cone-shaped pickup with different cone diameters, bunch length of 1 mm, bunch charge of 20 pC and a cone longer than the cut-out for 1 mm.

The curves show a certain trade-off between the V_{pp} and the slope. Namely, the increasing of the cone diameter leads to a longer duration of the voltage signal resulting in a more gradual slope at the zero-crossing. An optimal point would be the interception between the two curves. As the slope is specified to be higher than 300 mV/ps one can take an optimal area (marked in Fig. 2) for a maximum V_{pp}.

Table 1: Dimensions of the Cone and the Cut-Out for FLASH and the Modified Cone

Cone-shape pickup	Cone diameter	Cut-out diameter
For FLASH	2.4 mm	5.6 mm
Modified cone	6 mm	13.6 mm

The comparison between the cone-shaped pickup presented in [1] for FLASH and the modified cone-shaped pickup is shown in Fig. 3. The dimensions of the cone and the cut-out are given in Table 1.

From the results in Fig. 3 (top) one can see that the V_{pp} of the modified cone pickups is for factor 2 higher (V_{pp}=5 V) compared to the pickups at FLASH (V_{pp}=2.6 V). The slope at the zero-crossing is 299 mV/ps. The voltage spectrum of the modified cones (Fig. 3 (bottom)) on the other hand, has several resonance peaks and is below −10 dB for frequencies above 30 GHz. The resonances correspond to the increased diameter of the cut-out.

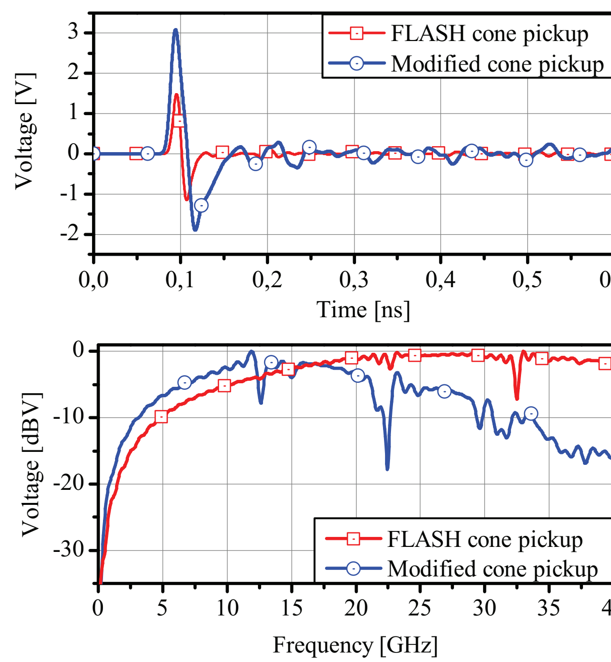

Figure 3: CST PARTICLE STUDIO® simulation of the cone-shaped pickup installed at FLASH and the modified version of the pickup for higher V_{pp}. Voltage signal in time domain (top), Voltage signal power spectral density (bottom).

NONHERMETIC DEMONSTRATOR

In order to measure the RF properties of the modified cone-shaped pickups we have built a non-hermetic demonstrator (see Fig. 4). Due to the limited manufacturing precision of the in-house mechanical workshop the dimensions of the produced pickups deviate from the ones presented in Table 1. However, the ratio between the cone and the cut-out diameter is 2.3 for a 50 Ω geometry in vacuum.

The diameter of the cone is 4.8 mm and the diameter of the cut-out is 11 mm. All of the components are made of brass. The four pickups are distributed in a four-fold rotational symmetry. The cone is paced in the middle of the cut-out and soldered to the glass bead of a 2.92 mm connector. A series of S-parameter measurements was conducted in order to characterize the pickups. The transmission co-

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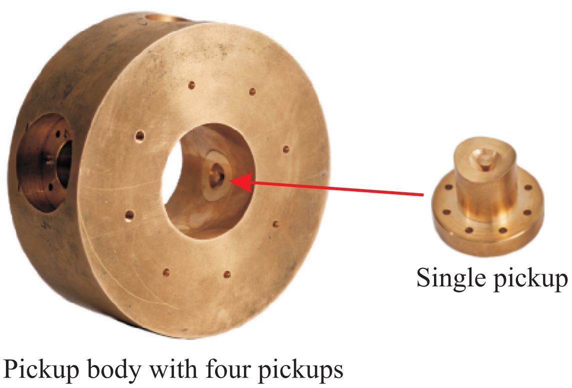


Figure 4: Photo of the nonhermetic prototype. Four pickups are integrated in the body.

efficient between the pickups which defines the cross-talk was measured and the results are compared to the simulation. Figure 5 shows the obtained results.

The measurements and the simulation are in a good agreement. Some resonance peaks in the measurement curve do not appear in the simulation. This can be due to the lack of resolution in the simulation over the broad frequency range and it is a subject of further investigation. The resonant peaks correspond to the distance between the pickups. The maximum cross-talk level is −12 dB.

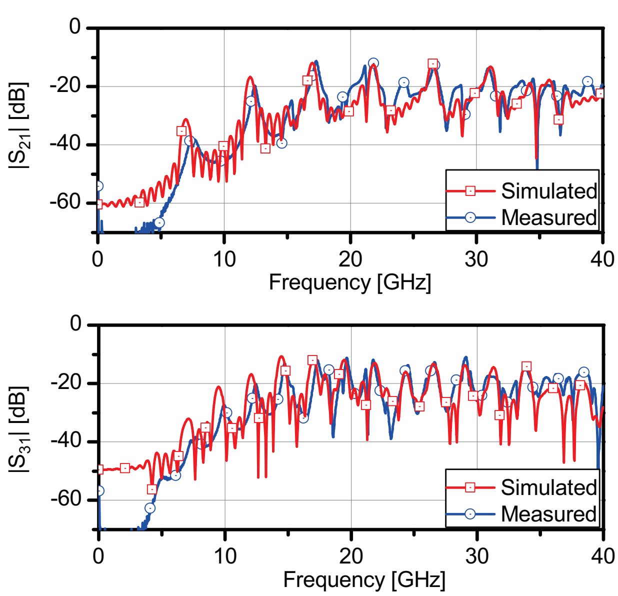
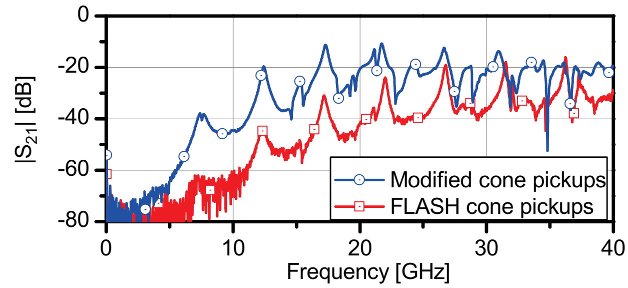


Figure 5: Comparison between simulation and measurements. Top: Between the neighboring pickups. Bottom: Between the opposite pickups.

A comparison of the cross-talk between the pickups for FLASH and the modified pickups is shown in Fig. 6. The cross-talk level of the modified pickup is up to 10 dB higher compared to the one of the FLASH pickups. This is due to the lager cut-out diameter of the modified pickups. In addition to that, the larger diameter of the cut-out causes resonances which can be seen at 25 GHz and 34 GHz.



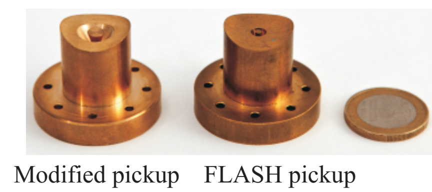


Figure 6: Top: Comparison between the pickup measurements of the nonhermetic prototypes for FLASH and the modified cone pickups. Bottom: Photo of the nonhermetic pickups.

CONCLUSION

In this paper a modified version of the cone-shaped pickups for FLASH introduced in [1] with improved peak voltage by factor two is presented. There is a certain tradeoff between the maximum voltage and the slope at the first zero-crossing of the pickup signal, i.e. bandwidth. An optimal area for the pickup design is proposed for obtaining a maximum peak signal with a slope steepness higher than 300 mV/ps and a bandwidth of 40 GHz. A nonhermetic demonstrator is built for measuring the RF properties of the pickups and the results are compared with the simulation. The cross-talk of the modified pickups is up to 10 dB higher than the one for the FLASH pickups.

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