Test of Digital Electronics for the p-LINAC BPMs at UNILAC

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Introduction

For the planned proton-LINAC at the FAIR facility [1], Beam Position Monitors (BPM) will be installed at 14 locations along the LINAC [2]. The digital signal processing to derive the transverse beam position and the beam velocity via time-of-flight determination could be implemented by so called Libera SPH (**Libera S**ingle **P**ass **H** **H**adron) electronic from company I-Tech [2,3]. The specification for position measurement is 0.1 mm spatial resolution averaged over one 30 ms long macro pulse. For time-of-flight beam velocity determination an accuracy of 10 ps is required corresponding to a phase of 1° with respect to 325 MHz acceleration frequency. A beam-based test was conducted at UNILAC to test the performance of Libera SPH electronics. For the same beam settings time-domain analogue signals were recorded with a 20 GSa/s oscilloscope for comparison. These time-domain data were Fourier-transformed and compared to the frequency-domain data from the Libera SPH.

Experimental Setup and First Results

The beam-based test was performed at UNILAC with a Ca^{10+} beam at 1.4 MeV/u and a beam current of ~ 80 µA. Using a buncher cavity for longitudinal focusing, several bunch shapes with different amplitudes and width were generated. A single BPM was used as a Bunch Arrival Monitor to further characterize the dependence of beam arrival time on bunch shape. The arrival time in time-domain was determined using zero crossing points with respect to a reference shape as depicted in Fig.1.

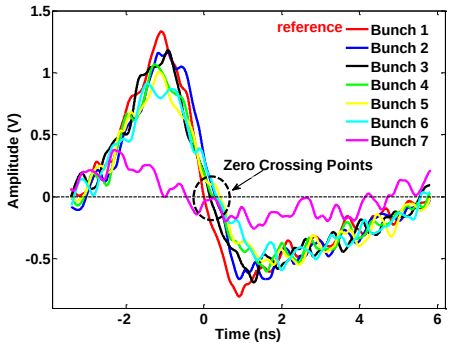

Figure 1: Time-domain recording of single bunches for different buncher cavity amplitudes are depicted to determine the individual zero crossing points.

The signals from a four plate BPM were sampled at 117.440 MSa/s with 16-bit ADC and digitally processed by Libera SPH unit to produce I and Q data stream for amplitude determination and phase calculation with respect to the 108.4 MHz acceleration frequecy. The RF analogue front-end of Libera SPH unit was customized for UNILAC parameters to perform the frequency-domain evaluation at the first two harmonics (108.4 MHz & 216.8 MHz). Using an amplification of 44 dB, the input peak voltages for seven bunch shapes recorded by Libera SPH were in the range of 0.57 V to 1.05 V.

As depicted in Fig. 2 the evaluated results showed some agreement between the Libera SPH phase readings and the time-domain measurements. Furthermore, Libera SPH processed the larger amplitude signals with a resolution of less than 1°. However, the FFT calculations of the single bunch data and the bunch stream are better matched to the time-domain evaluation.

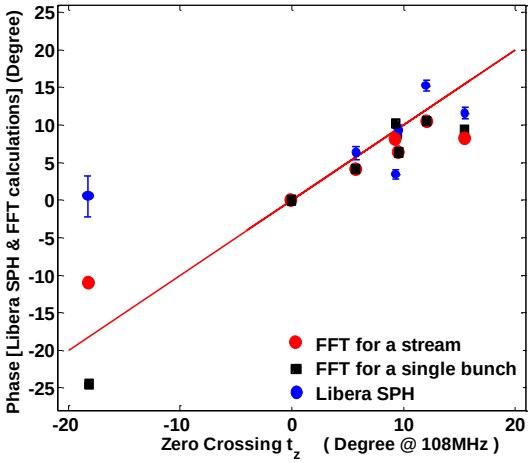

Figure 2: Time-domain data versus Libera SPH and FFT calculations for a single bunch and a stream of 30000 bunches.

Summary and Outlook

The tested Libera SPH digital electronics is suited for beam position determination but for phase detection it does not fulfil the requirements yet. However, modifications might lead to the desired accuracy. Therefore, further investigations are planned to improve the performance based on a comprehensive modelling of the digital signal processing algorithm.

References

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[2] P. Forck et al., "Design of the BPM System for the FAIR Proton-LINAC", GSI scientific report 2010.

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