DEVELOPMENT OF HIGH RESOLUTION MULTI-BUNCH BPM

H. Hayano, KEK, Tsukuba, Japan
S. Kashiwagi, The Graduate University for Advanced Studies, Tsukuba, Japan

Abstract

Measurement of wakefield[1] is planned at the Damping Ring extraction line of ATF, Accelerator Test Facility at KEK. In this experiment, 'residual' long-range transverse wake field excited by multi-bunch beam will be measured, and will be compared with theoretical calculation of wakefields with cell-to-cell misalignment. Since the multi-bunch beam from the Damping Ring is expected to be stable and extremely low emittance, we can measure a small transverse kick of 10 nrad by using 500 nm resolution BPMs and optimized optics of the extraction beam line. The design study of high resolution multibunch BPM is in progress. The progress of the multibunch BPM which will be used in both of this wakefield measurement and Linear Collider is reported.

1 INTRODUCTION

In the recent JLC design[2], a bunch train structure as 87 bunches of 9.8×10^9 electrons and 2.8 ns bunch spacing is used. In this multi-bunch design it is important to control the long-range transverse wakefields generated in the accelerating structures of the linac. The wakefield in the structure can be calculated by existing computer programs within certain limitations. It is important to make a comparison of the theoretical calculations with measurement using real beam. Until now, measurements of the wakefield suppression have been made on X-band detuned structure (DS) at Argonne's Advanced Accelerator Test Facility (AATF) and detuned damped structure (DDS) at ASSET. In ASSET, the measurement of wakefields was performed by using two bunches (electrons and positrons) which were injected into the system with individual control of the bunch timing and intensity. This experiment measured wakefield which was proportional to beam offset. On the other hand, our plan is to measure the wakefields using average centered multibunch beam which will be supplied from the ATF damping ring. Using ATF low emittance multibunch beam, the measurement of the residual wakefield which is induced by cell to cell misalignment of structure can be measured with high sensitivity, and the superposition effect of long-range transverse wakefield excited by multi-bunch beam will also be compared with the result of theoretical calculation. In this experiment, high resolution and high accuracy multibunch BPM is necessary and essential to detect a residual wakefield effect. Required resolution is 500nm for each bunch in a single shot measurement. The design study of pickup chamber and electronics are described in detail.

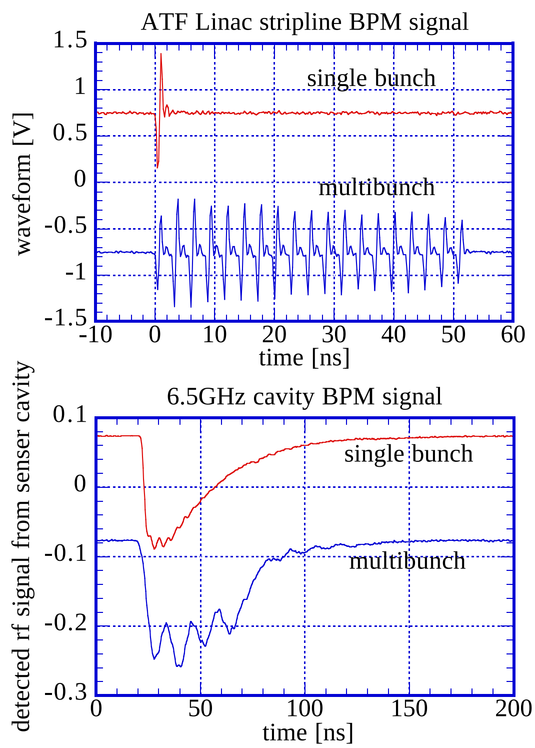

Figure 1: Examples of detected signal for single bunch and ATF multibunch by ATF Linac stripline BPM and 6.5GHz cavity BPM

2 DESIGN CONSIDERATION FOR MULTIBUNCH BPM PICKUP

2.1 Microwave cavity BPM

For high resolution single shot BPM, microwave cavity BPM and long stripline BPM will be a candidate to consider because of its high S/N ratio by the narrow band detection. In order to proceed to multibunch position detection in a single shot manner, a wide band detection is required additionally. In case of 2.8ns bunch spacing, the required band width will be determined by the response of the impulse like an excitation which is correspond to beam passing in the BPM. A microwave cavity has a relatively high Q-value compared to the bunch spacing for the mode which is used in position detection. The excited signal will not decay within a time of bunch spacing, but it will pile up to a certain equilibrium level. In order to resolve each bunch signal with high resolution, precise measurement of an amplitude and phase of a single bunch response is necessary to process the piled up signal. It seems, however, hard to resolve 2.8ns multibunch beam signal with enough resolution by a cavity with QL of several hundreds or more which is an ordinary for high resolution cavity BPM. Figure 1 shows examples of detected waveform for both of stripline and microwave-cavity of QL=600 in case of single bunch and ATF multibunch(19 bunches, 2.8ns separation). As for cavity BPM signal, following next bunch signal is piled up on its almost top of the peak. The trial of resolving them is under progress. On the other hand, stripline signal is well separated except its ringing tail.

2.2 Stripline electrode BPM

A stripline is the most adequate BPM for the multibunch detection. Since the beam signal is directly induced into a wideband transmission line, there is no capacitive effect like a long signal tail. The spectrum or the time structure of the induced bipolar signal is determined by the stripline length. When the stripline length is chosen to enough short than 2.8ns bunch spacing, the induced multibunch signal can be resolved in its time structure. For high resolution with some limitation on an electronics S/N ratio, we must choose small geometric conversion coefficient, that is, small bore diameter of BPM electrode. To get high precision for position detection of BPM center definition like a microwave cavity BPM, stripline electrode and its support should be considered as high precision.

Using reasonable electronics S/N ratio 3000 for 1GHz bandwidth, the required bore diameter will be less than 8.5mm for 500nm resolution. The required beam stay clearance of over 10σ of beam size will be around 4mm in diameter at the ATF extraction line. The stripline electrode diameter should be determined by these boundary conditions. The required stripline length should be determined by the bunch spacing 2.8ns, electronics bandwidth and the length of transmission coaxial cables. Assuming reasonable bandwidth of 1GHz, the impulse rise time to its maximum is around 300ps for a gaussian filter of n=4. In order to avoid loosing peak voltage of the first impulse swing, the separation of bipolar signal should be greater than 300ps which correspond to about 30mm stripline length. The maximum stripline length will be determined by the tail of the impulse response of about 900ps and the separation of bipolar signal. It will be 100mm. The tail of impulse signal is also increased by the length of coaxial cable between pickup and electronics. The stripline length should be determined by considering both of them.

3 PROTO-TYPE OF BPM PICKUP

In order to realize such a high resolution multibunch BPM, a stripline-type pickup chamber were adopted for this experiment purpose. Considering an application to a main linac BPM of the linear collider accelerator, absolute accuracy of less than 10μm which is correspond to cell to cell misalignment of the accelerating structure should be taken into account.

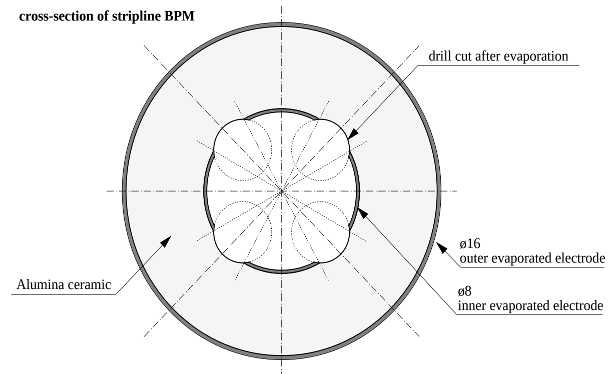

Figure 2: cross-section of ceramic and electrode part in prototype stripline BPM

To fabricate such a high accuracy small bore diameter stripline, metal evaporating and plating electrodes on an accurate machined ceramic base are employed(Fig. 2). The accuracy of stripline electrode is mainly determined by its support mechanism and connecting method between electrode and feedthrough connector. The evaporated electrodes on the precise machined ceramic provide a sufficient relative accuracy among electrodes of less than 10μm. The installation of the stripline ceramic into the chamber body will be done by another 10μm of accuracy. The connection method between feedthrough pin and thin evaporated electrode should be consider carefully in a view point of the accuracy. In this design, positioning of the feedthrough pin is done by 10μm machining accuracy and thin soldering connection of them will be applied.

The proto-type stripline BPM pickup chamber is shown in Fig. 3 with tapered transition chambers in its both end. The strip line length is chosen as 40mm and electrode bore diameter is chosen as 8mm. Since the dielectric constant of the ceramic is 9.8 and effective dielectric constant for microstripline is 6.7, the relative propagation velocity is 0.38. Therefore a reflection type of stripline is not adequate for resolving multibunch signal because of conflict superposition of gap signal and reflected signal at short end. The striplines are connected to SMA feedthrough connectors in both ends. One end of the upstream one is used for signal detection and the other end is terminated by a 50Ω load. The impedance of the stripline part is designed to have 50Ω by using a formula for a micro-stripline transmission in a flat substrate. This chamber is now under fabrication. Mechanical accuracy measurement by the precise three dimensional coordinate machine will be performed. Electrical center accuracy measurement by using stretched thin wire with electric pulse signal will be also performed. 50Ω matching of stripline to coaxial cable is also important for resolving bunch signal cleanly.

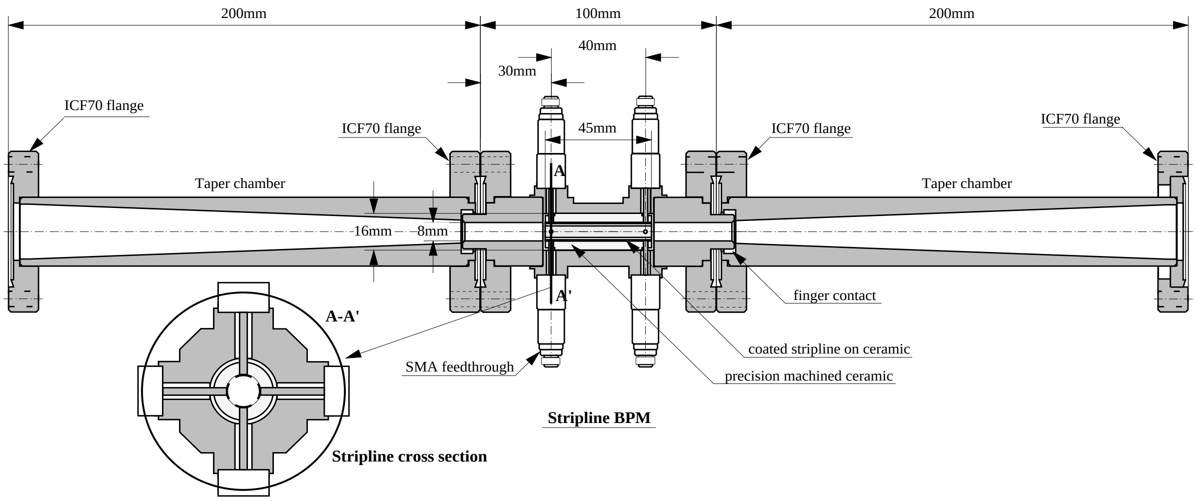

Figure 3: Proto-type stripline BPM pickup with taper chambers.

4 DESIGN OF PROCESSING ELECTRONICS

A direct Sample&Hold technique is used for detecting the extreme of each bunch signal. The required bandwidth to catch up and to resolve each bunch signal is greater than 850MHz which is determined by the electronics simulator program "PSpice". Using 850MHz gaussian low pass filter to stretch the signal and to make the signal peak flat, a systematic error of amplitude detection arising from a mixture of signal tail into the next bunch signal is estimated to 0.13%. The required S/N ratio to get 500nm resolution by the 8mm diameter stripline BPM is greater than 2958. The rms. thermal noise voltage for 850MHz bandwidth is 26.5μV which is enough small. The condition to get such a good S/N ratio is mainly determined by a fast S/H circuit limitation. The repetition of the sampling should be greater than 357MHz(2.8ns bunch spacing). It limits our selection to 8bit digital conversion circuit which has typical input range of 2V. In order to meet the resolution specification by using 8bit A/D conversion circuit, a direct signal subtraction and summation are used as shown in Fig. 4. The signal is amplified by G to overcome bit quantum resolution for the subtraction channel, and is attenuated by A to fit to the input range for the summation channel. The required gain for both channel should be G/A>11.7 in extreme case, that is minimum amplitude of subtraction channel and maximum amplitude of summation channel. The other critical issue for high resolution is timing jitter of fast S/H trigger. Because of very narrow flat-top of multibunch signal and comparable width of strobe gate, a timing jitter of several ps introduce directly an amplitude jitter of detected signal. In order to minimize it a self-trigger scheme is used for fast A/D conversion. The trigger signal is generated by using split summing signal with limiting amplifiers and constant fraction discriminator circuit. It is connected to the clock port of the 500MHz flash A/D CAMAC module. Detail design and circuit test is in under progress.

5 MULTIBUNCH BEAM

A low emittance multibunch beam generation is essentially necessary for this experiment. The key points are the generation of multibunch by the thermionic gun and beam energy compensation in the linac against the transient beam loading. The studies of these developments are in progress, and beam will be available in the autumn run of 1998.

6 ACKNOWLEDGMENT

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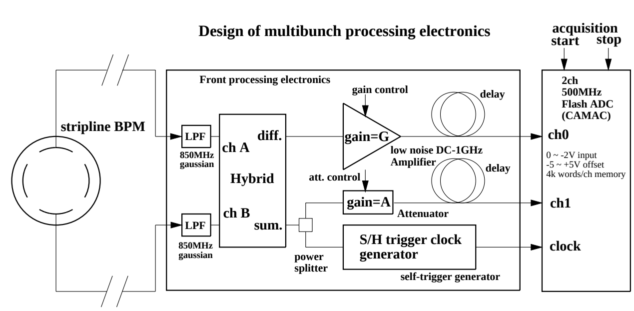

Figure 4: schematics of processing electronics design