NEW BEAM POSITION MONITOR ELECTRONICS FOR VEPP-5 PREINJECTOR

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Abstract

A new beam position monitor (BPM) electronics has been designed, manufactured and tested in VEPP-5 preinjector. Preinjector BPM system measures position of single electron and positron bunches for each injection cycle. New BPM electronics provides more high sensitivity with respect to existing one developed in 2004. The system can measure the position of bunches with 10^8 - 10^{10} particles per bunch. The resolution of measurements of single bunch is better than 10 µm for 10^{10} particles per bunch. The features of BPM electronics design, the main parameters and results obtained in VEPP-5 preinjector are presented.

INTRODUCTION

It is planned to put VEPP-5 preinjector [1] into regular operation in 2012. The preinjector produces electron and positron bunches with main parameters given in Table 1.

Table 1: Main parameters of the preinjector

Number of electrons in a bunch	$(2\text{-}3)\times10^{10}$
Number of positrons in a bunch	$(2\text{-}3)\times10^{8}$
Longitudinal bunch size	4 mm
Repetition rate for electrons for positrons	 1 Hz 50 Hz

The preinjector includes 300 MeV electron linac, conversion system and 510 MeV positron linac [1]. Existing Beam position monitor (BPM) system developed and fabricated in 2004 consists of 14 stripline BPMs and electronics [2]. The main problem with this system operation is insufficient position measurement accuracy of the positron bunches due to low signal-to noise ratio caused with interferences on the cables connecting BPMs with electronics. New BPM electronics developed in 2012 has signal-to noise ratio at least in one order better than old one. This improvement is achieved with help of two main changings:

- increasing of processing electronics bandwidth;
- decreasing of the timing circuit jitter.

Signal processing used in both new and old systems is low pass filtering. Signal amplitude at the Low Pass Filter (LPF) output U_{LPF} strongly depends on the LPF cut-off frequency F_{LPF}. In Fig.1 calculated dependence of the U_{LPF} value on the F_{LPF} for our sripline BPM signal is represented. In low frequency domain the signal amplitude grows with increasing of F_{LPF} almost as square of F_{LPF} value whereas the noise r.m.s. amplitude grows as square root of F_{LPF}.

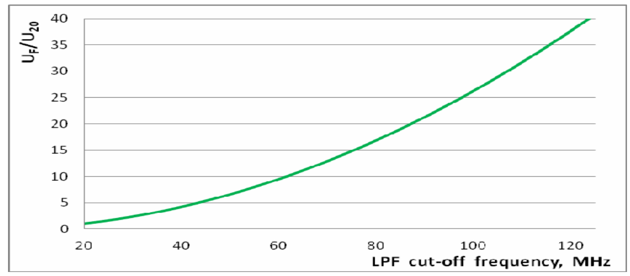

Fig.1. Calculated dependence of the relative signal amplitude in the LPF output U_F / U_{20} on the F_{LPF}.

In new electronics we have chosen F_{LPF} = 120 MHz. It is in 6 times more compare with old electronics. It gives a gain in signal-to-noise (S/N) ratio approximately in 15 times. Taking into account that main part of interference power is located in frequency domain 1-20 MHz total increasing of S/N ratio is more considerable. But increasing of the signal processing bandwidth imposes more hard requirements to jitter of the ADC clock signal. Therefore main efforts were applied to this aspect.

BPM ELECTRONICS STRUCTURE

A functional diagram of the new BPM electronics is presented in Fig. 2.

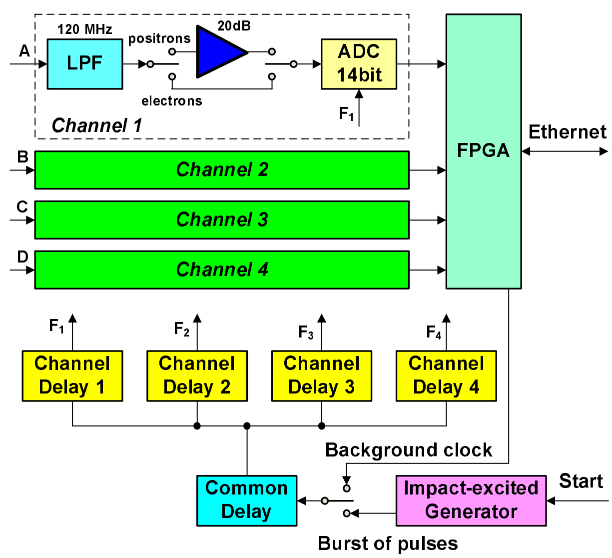

Fig.2. A functional diagram of the new BPM electronics.

The Electronics consists of four identical signal processing channels, timing circuit and FPGA. Signal processing channel contains LPF, switched amplifier and 14-bit ADC. The BPM signals are amplified by fixed gain

ISBN 978-3-95450-125-0

(~20 dB) amplifier if number of particles per bunch is less than 10^9 (for positron bunches). For electron bunches with number of particles more than 10^9 the signals bypass the amplifier.

A key part of the electronics is timing circuit which produces ADC clock signal. Pulse “Start” tied with gun shot causes generation by impact-excited generator a burst of 32 pulses with period of ~17 ns (Fig.3).

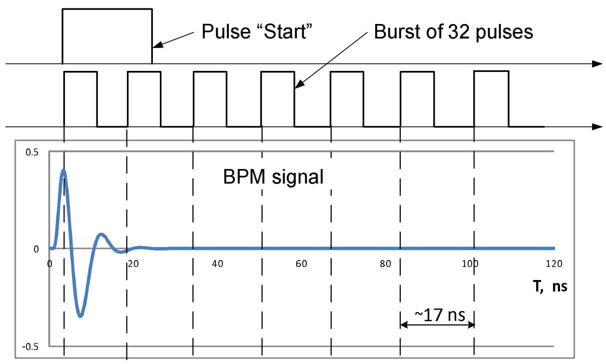

Fig.3. A time diagram of the timing circuit.

The burst of pulses passes through two-level fine delay. The first level delay on base of MC100EP195B is common for all four channels. It has delay range ~10 ns and delay step ~10 ps. The second level delay on base of the same chip MC100EP195B is individual for each channel. Ability of individual delay adjustment for each BPM electrode allows us to eliminate the problem of different cables lengths. The total fine delay range is about 20 ns. It overlaps the period between burst pulses. After gun shot we have for each BPM electrode a digital array of 32 ADC samples. We use only one sample which is more close to the top of the BPM signal. Adjusting the fine delay we set the rising edge of the clock pulse corresponding to this sample exactly on the signal top. The measured jitter of the timing circuit is about 13 ps. It caused mainly by the fine delay.

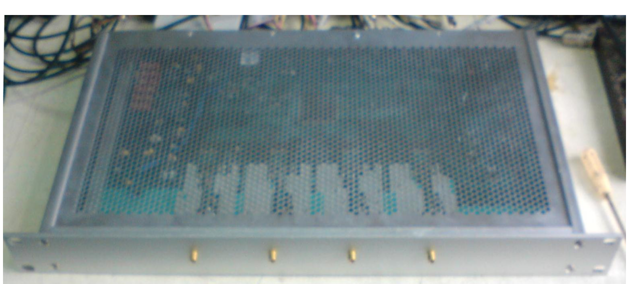

Fig.4. Prototype of BPM electronics.

Pipeline-type ADC requires continuous clock signal for correct work. So the large time intervals between the bursts of pulses are filled with background clock with frequency ~58 MHz from FPGA. Besides of the BPM signal amplitude zero levels for all ADCs are measured after every shot.

BPM electronics for one BPM occupies one 1U 19” chassis (Fig.4).

EXPERIMENTAL RESULTS

Prototype of new BPM electronics has been fabricated and tested with beam at VEPP-5 Preinjector.

For defining of single bunch position measurement resolution the special test had been made. The signal from one of BPM striplines was applied via four-way splitter to four inputs (Fig.5).

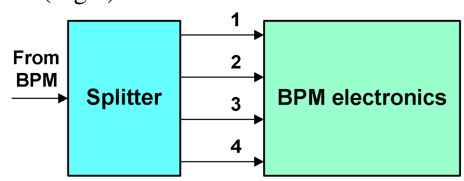

Fig.5. The test scheme.

Resolution was measured with two different numbers of electrons per bunch. The results are represented in Fig.6.

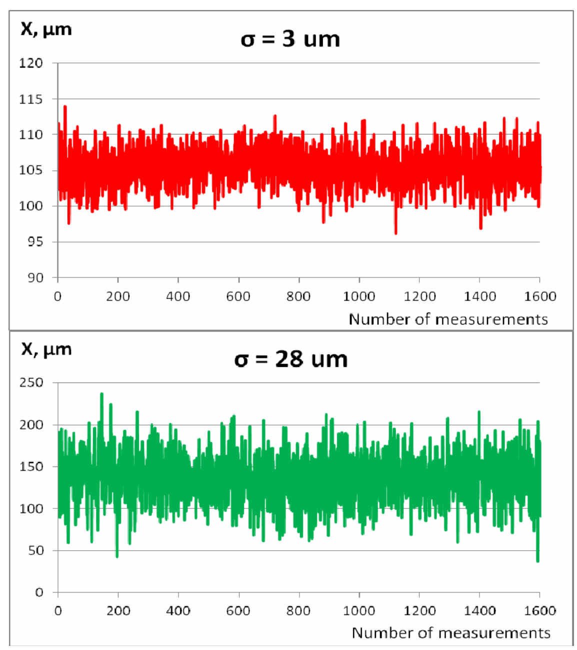

Fig.6. Results of the test with electron beam with number of particles per bunch $\sim 0.5\times10^{10}$ (upper picture) and $\sim 2\times10^8$ (lower picture).

Resolution of measurements for number of particles per bunch $\sim 0.5\times10^{10}$ is about 3 μm. For number of particles per bunch $\sim 2\times10^8$, which equals to nominal number of positrons per bunch, resolution is about 30 μm. Note that accumulation of data during the time 1 sec for positrons improves the resolution in 5-7 times.

Connecting each BPM electrode to its own input we had got the results represented in Fig.7. In this case root-mean-square deviation of measured beam position for number of particles per bunch $\sim 0.5\times10^{10}$ was ~18 μm. It is in six times more then electronics measurement

ISBN 978-3-95450-125-0

resolution for such bunch charge and caused by real instability of the beam position in the linac. However it less then electronics resolution for small numbers of particles per bunch (~2×10^8) corresponding to positrons.

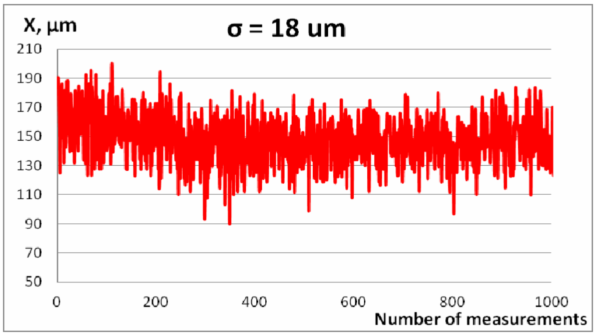

Fig.7. Results of horizontal beam position measurements for number of particles per bunch ~0.5×10^{10}.

Measured main accuracy parameters for $K_X \approx K_Y \approx 6$ mm are presented in Table 2.

Table 2: Accuracy parameters of the BPM electronics.

Dependence of the result on number of particles per bunch ($N = 10^9$-10^{10})	< 4 µm
Resolution for single bunch $N = 2\times10^8$ $N = 10^{10}$	 < 30 µm < 3 µm
Resolution for measurement time 1 sec $N = 2\times10^8$	 < 5 µm
Dependence of the result on the temperature	< 0.2 µm/°C

SUMMARY

Developed at BINP new BPM electronics for VEPP-5 preinjector has better accuracy parameters in comparison with old one. Tests with beam had shown ability of the electronics to measure positrons beam position with sufficient accuracy. Accumulating the data during the time 1-2 sec allows achieving almost the same measurement resolution for positrons as for electrons. It is planned to produce all electronics and to install it in preinjector before the end 2012.

REFERENCES

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ISBN 978-3-95450-125-0