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BEAM POSITION MONITOR SYSTEM FOR HIGH VOLTAGE ELECTRON COOLER FOR NICA COLLIDER

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Abstract

The high voltage (2.5 MV) electron cooler for NICA collider is now designing in BINP. Beam position monitor (BPM) system for orbit measurements has been developed at BINP. The system contains 16 BPMs inside the cooling sections, 4 BPMs inside the high voltage vessels and 22 BPMs in transport channels. Continuous electron beam is modulated with 10 MHz sinusoidal signal for capability to get signals from pickup electrodes. The beam current modulation can be varied in the range of 0.3-5 mA. The modulation signal may be supplied to each sector of the control electrode. So, the position of one quadrant sector of the electron beam can be measured by BPM system. Comparing the positions of each sectors from BPM to BPM it is possible to analyse the shape of the electron beam in the transport channel and cooling section. The BPMs inside the cooling section can measure both electron and ion beams. It is achieved by means of switching the reference signals inside the BPM electronics. The prototypes of new BPM electronics have been fabricated and tested. The BPM electronics provides highly precise beam position measurements. Position measurement error doesn’t exceed a few micron. Design features of the BPM system, its parameters and testing results are presented in this paper.

INTRODUCTION

The high voltage (2.5 MV) electron cooler for NICA collider is now designing in BINP [1]. Beam position monitor (BPM) system consists of 42 BPMs and electronics. 16 BPMs are located inside the cooling sections, 4 BPMs are installed inside the high voltage vessels and 22 BPMs are installed in transport channels. Continuous electron beam current is modulated with a ~10 MHz signal for capability to get signals from BPM electrodes. Some parameters of cooler and main BPM system requirements are presented in Table 1.

Table 1: Main Requirements to BPM System

Electron current	0.1-1 A
Modulation amplitude of electron current	0.3-1.5 mA
NICA collider revolution frequency F_0	523-586 kHz
Number of ion bunches N_b	22
Position measurement error	< 100 µm
Measurement rate	0.1-1 sec

To achieve the best cooling effectiveness electron and proton beams must be aligned inside the cooling section with accuracy better than 100 µm. This condition requires simultaneous measurements of electron and proton beams position by 16 BPMs located inside the cooling sections. 22 BPMs in the transport channels and 4 BPMs inside the high voltage vessels measure only electron beam position. A feature of the gun four-sector control electrode using before in the COSY cooler allows measuring not only electron beam position but the beam shape and rotation [2].

SYSTEM STUCTURE

The structure chart of the BPM system is presented in Fig. 1.

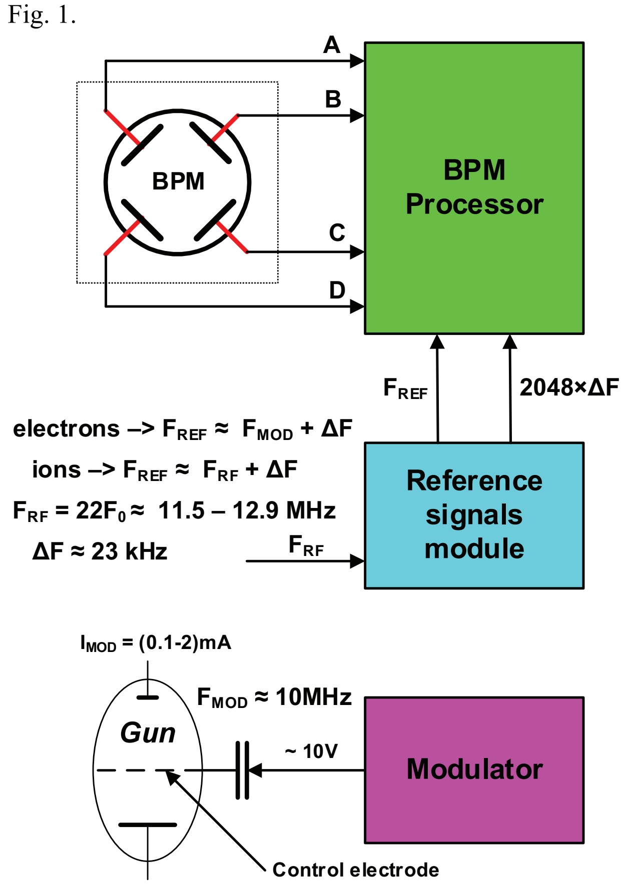

Figure 1: The structure of the BPM system.

The system consists of 42 BPMs, Signal Processing Electronics, including 21 BPM Processors and 38

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Preamplifiers, 2 Modulators, 1 Reference signals generator and 1 Reference signals distributor.

Modulator provides electron beam current modulation with frequency $F_{MOD} \approx 10$ MHz. Signal Processing Electronics measures the beam signals amplitude at each of four BPM electrodes. The measurement is based on synchronous detecting of the BPM signal with frequency F_{SIGN}. For BPMs inside the cooling sections F_{SIGN} equals F_{MOD} for electron beam and F_{RF} for ion beam, where $F_{RF} = 22F_0$. Revolution frequency F_0 is changed from 523 kHz to 586 kHz during acceleration in the NICA collider. For BPMs in the transport channels and guns F_{SIGN} equals F_{MOD}. The sinusoidal signal with frequency $F_{REF} \approx F_{SIGN} + \Delta F$ generated by Reference signals module is used as reference signal.

The simultaneous measurements of electron and ion beams position inside the cooling sections is achieved by means of switching the reference signal between $F_{MOD} + \Delta F$ and $F_{RF} + \Delta F$.

ELECTRONICS

Modulator

The system contains 2 Modulators – one modulator for each Gun. A functional diagram of the Modulator is presented in Fig. 2.

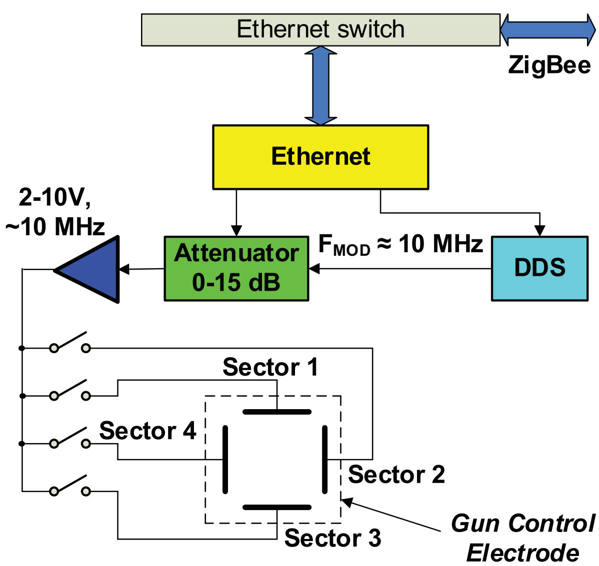

Figure 2: Functional diagram of the Modulator.

Gun Control electrode consists of four sectors. Modulation voltage can be applied both to all sectors and to one of them. In the last case only a part of electron beam in transverse cross-section will be modulated. By switching on different sectors in turn one can get information about the beam shape and beam precession due to longitudinal field in different BPM locations [2].

Modulator is located inside the High Voltage (HV) tank at potential of up to 2.5 MV. Modulation signal with frequency $F_{MOD} \approx 10$ MHz is generated by DDS. An amplitude of modulation voltage can be set in the range 2-10 V with help of programmable attenuator.

Signal Processing Electronics

Functional diagram of the Signal Processing Electronics for BPMs inside the cooling sections and transport channels is presented in Fig. 3.

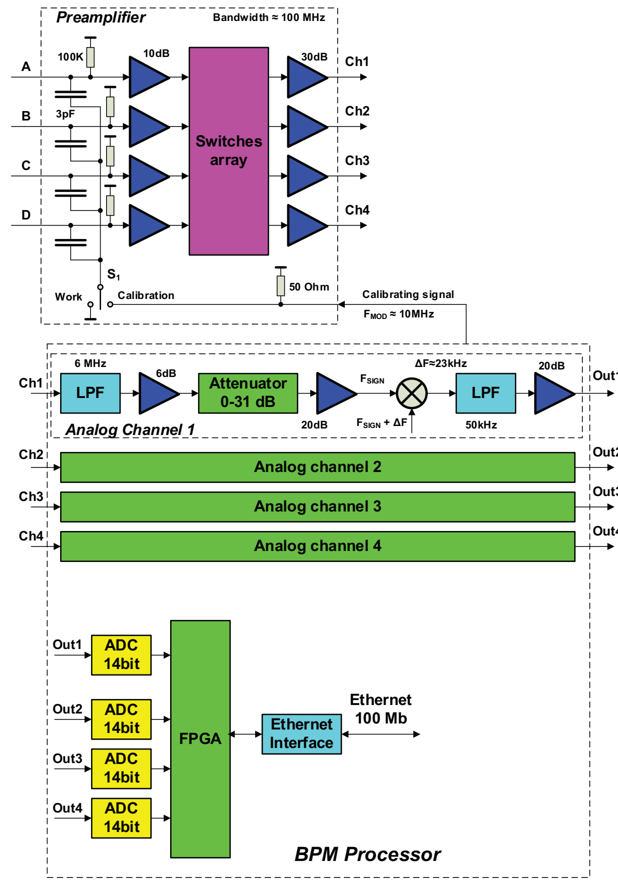

Figure 3: Functional diagram of the Signal Processing Electronics for BPMs inside the cooling sections and transport channels.

Signal Processing Electronics for each BPM inside the cooling sections and transport channels consists of Preamplifier with high input impedance located near BPM and BPM Processor. Preamplifier is connected with BPM via four 75 Ohm cables with length ~1 m. BPM Processors are placed in the rack located in the electronics room. Switches array used in Preamplifier provides 4 connection combinations between 4 BPM electrodes and 4 signal processing channels. Use of the Switches array allows to eliminate measurement error caused by inequality of the channels transmission coefficients.

After amplification the BPM signals with frequency F_{SIGN} are mixed with reference frequency $F_{REF} \approx F_{SIGN} + \Delta F$. Then the signals with frequency $\Delta F \approx 23$ kHz after low pass filtering and amplification are sampled by 14 bit ADC. The signals in digital form come to FPGA where digital processing is performed. This digital signal

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processing includes synchronous detecting and accumulation. The frequencies F_{MOD} and F_{REF} are generated by different modules. So, for electrons F_{REF} value is not exactly equaled to $F_{MOD} + \Delta F$. A difference between the reference frequency F_{REF} and $F_{MOD} + \Delta F$ for proper synchronous detecting must be less than 1 kHz. To achieve this a tracking of the reference frequency F_{REF} to $F_{MOD} + \Delta F$ is implemented. The tracking procedure includes measurement of the difference between F_{REF} and $F_{MOD} + \Delta F$ values on base of spectrum of ADC data.

In calibration mode special calibrating signal with frequency $F_{CAL} \approx 10$ MHz comes through the switch S_1 and capacitances to each Preamplifier input (see Fig. 3).

BPM Processor occupies one 1U 19" chassis (Fig. 4). Each BPM Processor can serve two BPMs.

Figure 4: BPM processor prototype.

Signal Processing Electronics for BPMs inside the guns is fully located within one module BPM Processor (1U 19" chassis). It has not the Preamplifiers in separate bodies. Reference signal F_{REF} and calibrating signal F_{CAL} are generated inside the BPM Processor.

EXPERIMENTAL RESULTS

Prototypes of all BPM electronics modules have been fabricated and tested. Main accuracy parameters have been measured with using of the signal generator. A sinusoidal test signal with frequency ~10 MHz was applied via four-way splitter to four Preamplifier inputs. Signal amplitude was changed in the range 0.2-1 mV which corresponds to beam current modulation range 0.3-1.5 mA. Three measured main parameters of accuracy (for $K_X \approx K_Y \approx 40$ mm) are presented in Table 2.

Table 2: Main Accuracy Parameters of the BPM System

Dependence of the result on beam modulation current (I_{MOD} = 0.3-1.5 mA)	~4 µm
Resolution (I_{MOD} = 0.3-1.5 mA)	< 1 µm
Dependence of the result on the temperature	~2 µm/°C

An accuracy achieved with prototypes satisfies all cooler requirements.

STATUS

All BPMs and electronics are fabricating now in BINP. It is planned to complete fabrication and testing all the BPM electronics modules in 2020 year.

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