

# BEAM POSITION MONITOR SYSTEM FOR 2 MEV ELECTRON COOLER FOR COSY

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## Abstract

The 2 MEV electron cooler for COSY storage ring FZJ is assembling in BINP. Beam position monitor (BPM) system for orbit measurements has been developed and fabricated at BINP. The system contains 2 BPMs inside the cooling section and 10 BPMs in transport channels. Continuous electron beam is modulated with a 3 MHz signal for capability to get signals from pickup electrodes. The beam current modulation can be varied in the range of 0.3-1.5 mA. The BPMs inside the cooling section can measure both electron and proton beams. It is achieved by means of switching the reference signals inside the BPM electronics. The BPM electronics provides highly precise beam position measurements. Position measurement error doesn't exceed 1 micron. Design features of the BPM system, its parameters and testing results are presented in this paper.

## INTRODUCTION

The 2 MEV electron cooler for COSY storage ring FZJ has been designed and assembled in BINP [1, 2]. Beam position monitor (BPM) system consists of 12 BPMs and electronics. 2 BPMs are located inside the cooling section. 10 BPMs are located in transport channels. Continuous electron beam current is modulated with a ~3 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	0.1-3 A
Modulation amplitude of electron current	0.3-1.5 mA
Proton current	0.1-2 mA
COSY RF frequency	~0.5-1.5 MHz
Position measurement error	less than 100 $\mu\text{m}$
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  $\mu\text{m}$ . This condition requires simultaneous measurements of electron and proton beams position by 2 BPMs located inside the cooling section. 10 BPMs in the transport channels measure only electron beam position. A new feature of the gun four-sector control electrode allows measuring not only electron beam position but the beam shape and rotation [2].

## SYSTEM STRUCTURE

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

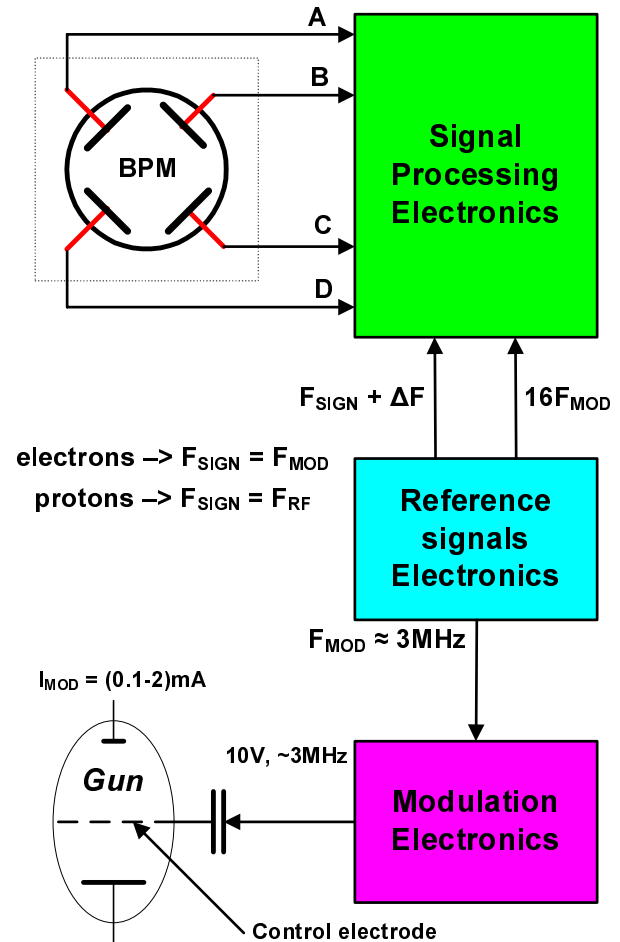


Fig.1. The structure of the BPM system.

The system consists of 12 BPMs, Signal Processing Electronics, Modulation Electronics and Reference signals Electronics. The four-electrode electrostatic BPM for transport channels is represented in Fig.2.

Modulation Electronics provides electron beam current modulation with frequency  $F_{\text{MOD}} \sim 3$  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  $F_{\text{SIGN}}$ , which equals  $F_{\text{MOD}}$  for electron beam and  $F_{\text{RF}}$  for proton beam. The sinusoidal

signal with frequency  $F_{SIGN} + \Delta F$  generated by Reference signals Electronics is used as reference signal.



Fig.2. A piece of vacuum chamber with BPM.

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

## ELECTRONICS

### Modulation Electronics

A functional diagram of the Modulation Electronics is presented in Fig.3.

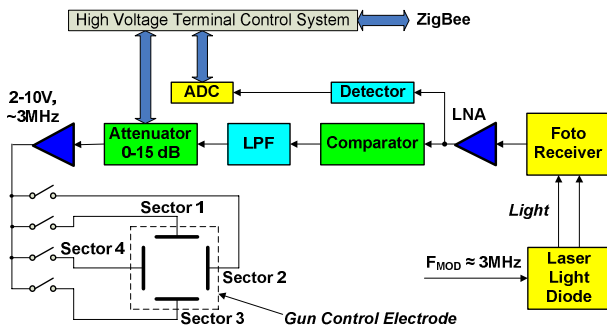


Fig.3. Functional diagram of the Modulation electronics.

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].

Main part of Modulation electronics is located inside the High Voltage (HV) tank at potential of up to 2 MV. Modulation signal ~3 MHz is transmitted to high voltage part by means of light. Laser diode ADL-66505TL mounted on HV tank flange is used as optical transmitter.

Its optical output power is stabilized at the level of 20 mW. Silicon PIN photodiode BPW34 located at ~0.3 m distance from laser diode is used as optical receiver. Combination of low noise amplifier (LNA) and comparator allows us to have a stable modulation voltage at the control electrode even for sufficient deviation of optical transmitter angle from optimal – up to 10 degrees. Measuring the modulation voltage at the LNA output by means of detector and ADC allows optical transmitter angle adjustment for maximization of optical power coming to optical receiver.

### Signal Processing Electronics

Functional diagram of the Signal Processing Electronics is presented in Fig. 4.

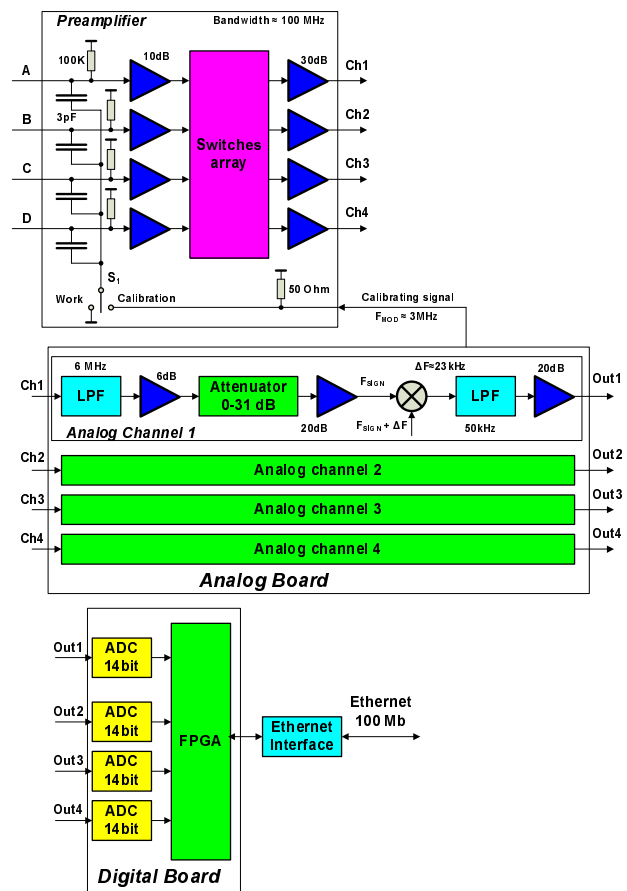


Fig.4. Functional diagram of the Signal Processing Electronics.

Signal Processing Electronics for each BPM consists of Preamplifier with high input impedance located near BPM and BPM Processor which has two boards: Analog board and Digital board. Preamplifier is connected with BPM via four 75 Ohm cables with length 1.2 m. 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  $F_{\text{SIGN}}$  are mixed with reference frequency  $F_{\text{SIGN}} + \Delta F$ . 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 processing includes synchronous detecting and accumulation.

In calibration mode special calibrating signal with frequency  $\sim 3$  MHz comes through the switch  $S_1$  and capacitances to each Pre-amplifier input.

BPM Processor occupies one 1U 19" chassis. Each BPM Processor can serve two BPMs.

## EXPERIMENTAL RESULTS

BPM system has been fabricated and tested. Since November 2011 the system works in the cooler with electron beam at the BINP test stand.

To define the measurements accuracy a sinusoidal test signal with frequency  $\sim 3$  MHz was used. It was applied via four-way splitter to four Pre-amplifier 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  $K_X \approx K_Y \approx 43$  mm) are presented in Table 1.

Table 1: Main accuracy parameters of the BPM system.

Dependence of the result on beam modulation current ( $I_{\text{MOD}} = 0.3-1.5$ mA)	$\sim 4$ $\mu\text{m}$
Resolution ( $I_{\text{MOD}} = 0.3-1.5$ mA)	$< 1$ $\mu\text{m}$
Dependence of the result on the temperature	$\sim 2$ $\mu\text{m}/^\circ\text{C}$

In Fig.5 results of continuous beam position measurements with one of the BPM (№5) with modulation current  $I_{\text{MOD}} \approx 1$  mA are represented.

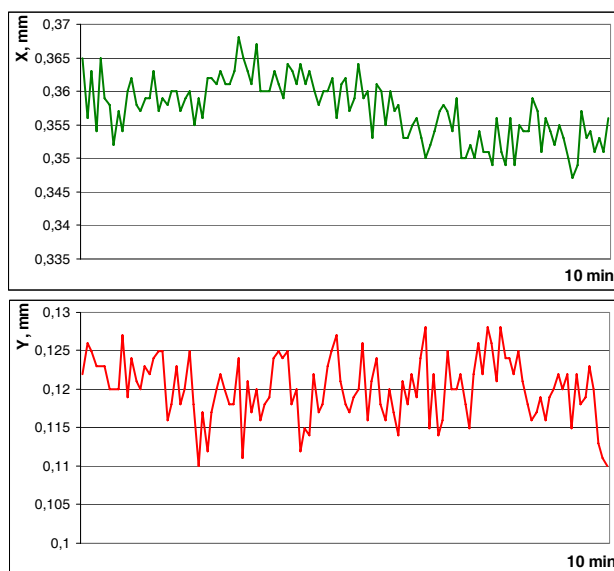


Fig.5. Results of horizontal (upper figure) and vertical (lower figure) beam position measurements for BPM №5.

Root-mean-square deviation of measured beam position for most BPMs is at the level of 4-6  $\mu\text{m}$ . It is more than system measurement resolution and can be caused by real instability of the beam position in the cooler.

Applying of the modulating voltage to separate Gun Control electrode sectors gives possibility to get information about beam shape. In Fig.6 beam positions for three different BPMs are represented.

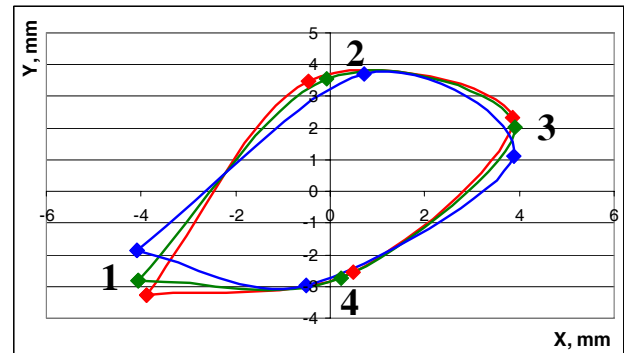


Fig.6. Measured beam positions for three different BPMs:

- red colour – BPM №2
- green colour – BPM №4
- blue colour – BPM №10.

Points “1” correspond to the case when modulating voltage was applied only to sector 1, points “2” correspond to the case when modulating voltage was applied only to sector 2 and so on. One can see approximate beam shape and its rotation.

## SUMMARY

Developed and fabricated at BINP BPM System satisfies all cooler requirements. Since November 2011 BPM system is successfully working with beam at the BINP test stand. Regular work at COSY storage ring is planned before the end 2012.

## REFERENCES

- [1] J. Dietrich at al/ “Status of 2 MeV electron cooler for COSY-Julich/HESR” // PAC’11 New York, NY, USA, WEP229, p.1918-1920.
- [2] V. Reva at al/ “The first commission results of the high voltage magnetized cooler for COSY” // COOL’11 Alushta, Ukraine, THIOA02, p.37-42.