

SOFTWARE AND CAPABILITIES OF THE BEAM POSITION MEASUREMENT SYSTEM FOR NOVOSIBIRSK FREE ELECTRON LASER

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Abstract

The system that measures the electron beam position in Novosibirsk free electron laser with the application of electrostatic pick-up electrodes is described. The measurement hardware and main principles of the measurement are considered. The capabilities and different operation modes of this system are described. In particular, the option of simultaneous detection of accelerated and decelerated electron beams at one pick-up station is considered. Besides, the operational features of this system at different modes of FEL performance (the 1st, 2nd, and 3rd stages) are mentioned.

INTRODUCTION

A high-power free electron laser (FEL) based on the accelerator-recuperator [1] is under construction now at Budker Institute of Nuclear Physics. The first and second phases of the project were commissioned recently. The beam position measurement system is one of the important diagnostic systems of the FEL. The system consists of a large amount of electrostatic pick-up electrodes installed on the vacuum chamber of the microtron-recuperator and special measuring devices located outside the accelerator hall. The main characteristics, measurement algorithm and capabilities of this system are described in this paper.

SYSTEM STRUCTURE

As mentioned above, the main part of the system is a number of pick-up electrodes (BPM stations) installed in different parts of the vacuum chamber of the microtron-recuperator. Each BPM station has four buttons with a clear aperture diameter of about 80 mm. Signals from the plates of all BPMs are transmitted by cables outside the shielded hall to the site of location of the measurement electronics. The beam position is determined via simultaneous measurement of the amplitudes of signals induced on the buttons by the beam field. It is done with the use of the following linear approximation formula:

$$x = k \frac{U_+ - U_-}{U_+ + U_-},$$

where k is a factor with the dimension of length. It is obtained from electromagnetic measurements (in the case of a circular tube, $k \cong a/4$, where a is the tube radius); U_+ and U_- are the amplitudes of signals from a pair of opposite (left and right) plates.

Due to the principle of operation of the microtron-recuperator, there are simultaneously several electron beams at some places of beam propagation. For example, accelerated and decelerated beams are moving simultaneously in the accelerating RF section. The total

number of different beams in the RF section depends on the number of beam turns and equals $2*N$ (where N is the number of turns). Owing to this feature, the task of separated measurement of the positions of different beams at the same BPM station arises. This task influenced the choice of the measurement hardware and the measurement algorithm.

The main devices used in this system are as follows:

- a 4-channel analog-to-digital converter with a 32k-memory cell per each channel and external start,
- a 4-channel delay line with a step of time delay adjustment of 250 psec, and
- a 5-channel multiplexer

All these devices are manufactured in the CAMAC standard. A more detailed description can be found in [2].

The principle of measurement is shown in Fig. 1.

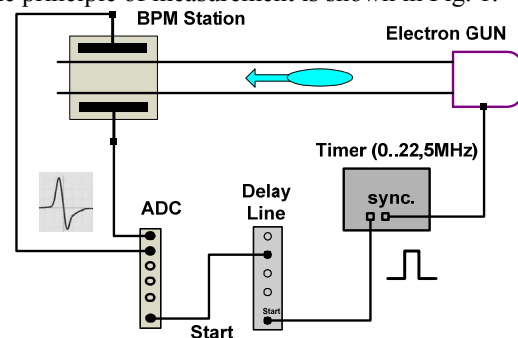


Figure 1: Scheme of beam position measurement.

The measurement is performed by the 4-channel ADC, to which 4 cables from the BPM plates are connected. The moment of measurement is determined by an external “Start” signal. This signal is generated by the Timer – a device that also sends a control signal to the electron gun modulator. Thus the frequency of the “Start” signal is equal to the frequency of the movement of the electron beams. For compensation of the difference in the time of movement of all these signals and time of beam movement in the vacuum chamber, the “Start” signal is passed through the adjustable delay line. A precise adjustment of the time delay value allows one to select the time of measurement, tune the measurement moment to the pulse maximum, and also to tune the measurement to different beams, moving one after another. Since the number of BPM stations is rather large, the measurement devices are grouped in units. Each unit contains one ADC and five multiplexers, so it is possible to connect five BPMs. Besides, each unit uses one channel of the delay line. So, since a CAMAC crate can hold up to three units, there should be one delay line in each CAMAC crate. The entire scheme of this system, connections of the BPM electrodes and measurement devices are presented in Fig.2.

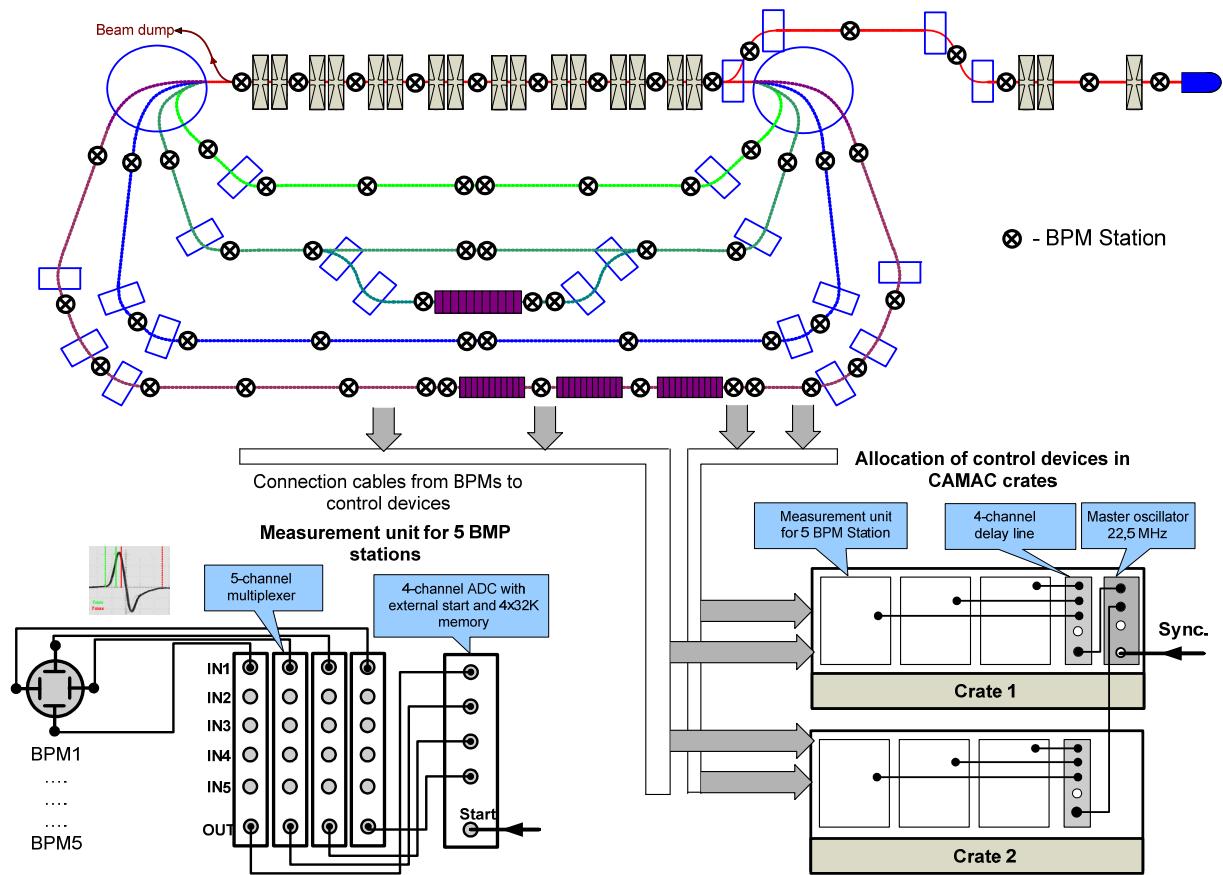


Figure 2: Main scheme of the beam position measurement system.

SOFTWARE

The control software for this system is a single application running on the IBM-PC computer. Communication with the CAMAC crates is realized with the help of the ISP controller, developed at Budker INP. The application can operate in several different regimes.

The first regime is a serial poll of all the BPM stations for the purpose of determination of the transverse coordinates of the beam (the main operating regime). In this regime, the application is subsequently polling all BPM stations. Measurement at each BPM station is executed in a specified delay time range assigned to the delay line. After running throughout the range, the program finds the maximum of signals from each button, computes the transverse coordinates, and displays it either as the beam trajectory or as the beam positions at each station (see Fig.3). In this case, measurement of one point requires ~15 CAMAC NAF instructions and a time of approximately 1 millisecond. Usually, each BPM station has a range of about 10-15 time delay points. So, for the FEL 1st stage with 37 measurement points in total, the overall time of measurement of the entire beam trajectory is 400-600 msec.

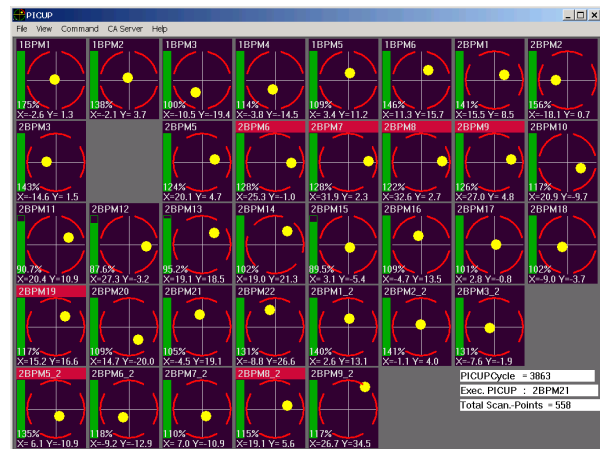


Figure 3: Window of a serial poll of the BPM stations.

Besides the calculation of transverse coordinates, in this regime the application calculates the sum of all maximum measured signals since this value is proportional to the value of electron beam current. The user can select any BPM station, and the application will calculate the beam current value in percents relative to this value on the selected BPM. The “relative” beam current value is drawn in the main window with green vertical bars. With this feature it is very easy to find areas of the accelerator track with beam current losses.

The second operation regime is a scanning throughout the delay time range of one of the BPM stations. While

executing this cycle, the program plots the time dependence graph of the beam-generated pulse. If there are several different beams at a selected BPM station, the user can view them in the same graph. The resulting plots of this regime are shown in Fig. 4. This regime is mainly used for specification of the time delay limits for scanning in the main, first regime. The user can manually select the time delay range as narrow as possible to reduce the time of processing of this BPM station. At the same time, this range should include all the four maximums of signals from the BPM buttons.

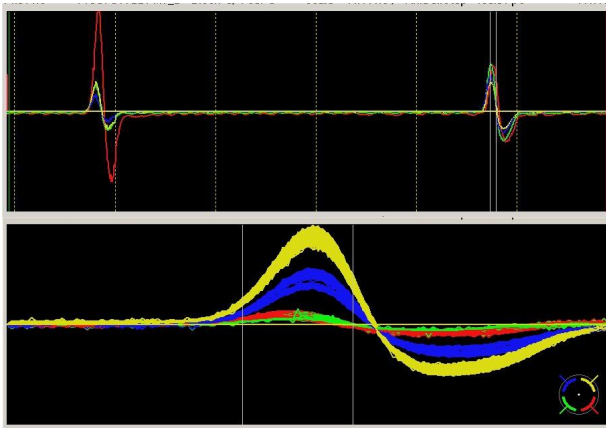


Figure 4: Graphs of the scanning cycle throughout the time delay range.

Another application of this regime is the study of the time stability of electron beam. The user can specify the scanning range as small as possible, containing only pulses from the buttons (see the lower part of Fig.4.). It is also possible to run this scanning cycle infinitely, without erasing the previous graphs. In this case, if there are some oscillations of beam position or beam current, the BPM button pulse graphs will cover the whole area of these oscillations.

The third and very useful regime is a poll of the waveform of the BPM button pulses with the frequency of the beam movement and a constant time delay value. As in the previous regimes, measurement is triggered by an external signal. However, in this case, measurement data are stored in the internal ADC. The ADC has a memory of 32 K of 12-digit words for each channel and can perform measurements with a frequency as high as 50 MHz. When the whole memory is filled, the application reads all the measurement data from it and plots them (see Fig. 5). Measurements in this regime being executed with the beam movement frequency, the amplitude, frequency, and shape of beam pulse oscillations, if any, can be found. Besides, modifying the beam pulse area where these measurements will be performed, one can easily study the nature of oscillations of beam positions or current.

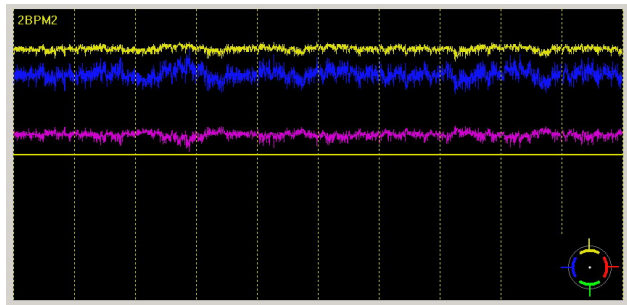


Figure 5: Plots of measurements with a constant time delay value and beam movement frequency.

Another useful feature of this application is the ability to transfer all measured data (the x and y coordinates and beam current) to another application in the FEL control LAN. For this purpose, a portable Epics Channel Access server is built-in inside the application. Every measured value is presented by one process variable.

CONCLUSION

The above-described system has been operating for about 8 years, demonstrating high reliability. The features of the measurement equipment allow observing simultaneously the accelerated and decelerated beams in the accelerator-recuperator beam-line. The interface and capabilities of the control software allow analyzing the behavior and time characteristics of the electron beam. The existence of the Epics Channel Access server in the program allows archiving all measured data and using them in other applications.

REFERENCES

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- [2] E.N.Dementiev, N.I.Zinevich, E.I.Shubin, "Atomic Energy", v.93, iss.6, December, 2002, pp.453-455.