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Fast Automatic System for Measurements of Beam Parameters of the MMF Linac

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Abstract

Fast transverse beam profile and current monitoring systems have been tested at the Linear Accelerator of Moscow Meson Factory. The signals for each system are derived from multiwire secondary emission chamber and beam current transformer. Each beam pulse is digitized by fast ADC's. There are two modes for systems. First one is for detailed beam adjustment and second one is for normal 100 Hz rate of the MMF Linac. Essential features of the hardware, software, data acquisition, measurement accuracy and beam results are presented.

1 Introduction

Systems for automatized measurement of beam parameters are components of general control systems of accelerators. Just through computerized measurement systems feedbacks enveloping accelerator completely or partially are closed [1]. Application of measurement systems permits first of all to make effective tuning of beam parameters such as transverse sizes, emittance and so forth, and, secondly (and it may be the most important) to reduce effects of radiation induced by the beam. This makes essentially easier exploitation conditions and conditions of tuning works, because for getting needful information about the beam it is necessary to spend essentially lesser beam time. Supposed installation in spaces between resonators of the first part of the MMF Linac measuring assemblies, consisting of multiwire electrodes, phase analyzer and target for energy estimation must solve tuning problems to a considerable extent.

In this paper it is considered principles of construction and main features of data treating systems, which permit to get as simple transverse profile of each whole beam pulse in usual exploitation regime as detailed picture of evolution of transverse profile and intensity for single beam pulse, and on the base of this information to estimate mutual influence of neutralization process and Coulomb's repulsion. Besides that high registration speed of profiles and intensity gives the base for hope on getting more full information needful for tuning of accelerator resonators by the beam.

Signals from multiwire chamber [2] and current transformer (Fig. 1) are treated through specialized set of modules and standard CAMAC modules. This set forms flexible enough complex of equipment, organizing the work as with objects placed near computer as with remote ones.

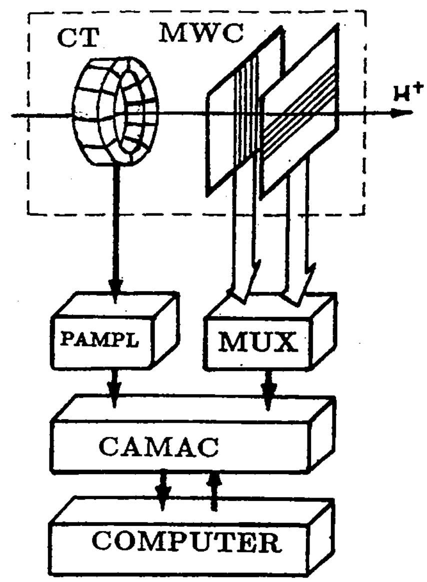

Figure 1: Simplified block diagram of beam parameter measurement system.

2 Speed criterion

Taking into account, that there will be approximately 650 analog signals from the wires placed in proton transfer channel (transfer channel is placed between injector and first accelerating resonator) and in spaces between resonators, it is easy to see, that detailed digitizing of these data by means of separate ADC for every wire is not simple and very expensive way. Therefore construction of system should be made by traditional way of storing and multiplexing of analog data. And criterion of information detailing one must search being attached not only to speed of ADC and computer, but mainly to physical processes

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and their characteristic frequencies, which may be studied, not converting treating system into too expensive one. In this case the most interesting tasks are ones bound up as mentioned above with influence of space charge neutralization, and also with inertness of resonator feedbacks. During beam injection it takes place ionization of residual gas in transfer channel, that can create at the beginning of beam pulse distinctive change of the form of the envelope because of change of the phase shift of radial oscillations. It can lead to unforeseen losses and to current limitation because of mismatching. Because neutralization time takes up $5\ldots10\mu s$ at designed vacuum (and greatly depends on vacuum), then this process can be observed only by fast enough system. As the system "resonator-feedback" has crossover frequency of 160 kHz, then for observing influence of this loop on the beam, diagnostic system must be a few times faster. In exploitation when tuning problems are solved the speed of measurements can be equal or less than 100 Hz repetition rate of the Linac.

3 Organization of measurement system

Proposed system consists of three parts :

- *Simple Profile Measurement system* (SPM), which permits to get profile of each pulse of the Linac by means of integration of the currents from the wires of Multiwire Chamber (MWC).
- *Beam Current Transformer system* (BCT), which permits to measure pulse current for each pulse of the Linac.
- *Fast Beam Parameter Measurement system* (FBPM), which permits to get series of beam profiles measured within one beam pulse at tuning Linac regime or permits to make SPM system measurement at normal 100 Hz Linac exploitation.

3.1 Simple Profile Measurement System

SPM hardware consists of analog signal multiplexer (MUX) which is installed near MWC at the Linac, and ADC in CAMAC crate, which is placed in accelerator control room. Methods of multiplexer construction are well-known [3,4] so we limit ourselves only to brief describing of its working. Simplified block diagram of device is given in Fig. 2 . Besides of input RC-circuits multiplexer consists of following parts: analog switches, control logical scheme, circuits of signal forming for switch control, output amplifier. Voltages accumulated on input capacitors are switched in turn to final amplifier and through cable line are fed to ADC. MUX logical scheme is started by external sync pulse SP coming to input of time delay generator (DG) which is needed for shifting of scanning beginning for a time sufficient for elimination of high-frequency

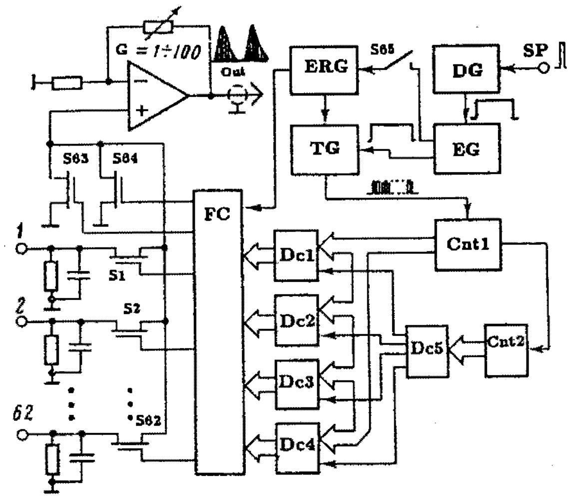

Figure 2: Block diagram of simple MUX.

inducings arising from high-power pulse equipment of accelerator. Generator of scanning envelope (EG) is started by decay of DG pulse and permits working of generator of scanning train (TG) . Pulses of TG are fed to counter Cnt1. Highest output of Cnt1 is connected to input of counter Cnt2. Cnt1 output code controls working of decoders Dc1 - Dc4, and Cnt2 code controls working of Dc5 which permits working of Dc1 - Dc4 in turn. Signals from Dc1 - Dc4 outputs converted by forming circuits (FC) open switches S1 - S62 in turn. Switch S63 is opened between scanning pulses and prevents charge accumulation on input capacitance of final amplifier. For determination of profile for each beam pulse there is unit in scheme for repeated start of system and discharge of capacitors. It consists of generator of envelope repetition (ERG) and switch S64 connected to final amplifier input. After closing the switch S65 every decay of EG pulse starts ERG, which opens S64 and permits to begin repeated cycle of scanning. Thus it is carried out in turn discharge of all capacitors through switches S1 - S62 and switch S64.

One of the advantages of computer treating is subtraction of voltages existing on the capacitors when no beam passes through MWC. Storing and subtracting of low-frequency inducings permit us almost completely to eliminate their influence on measurement results.

3.2 Beam Current Transformer System

BCT system consists of low noise preamplifier (PAMPL) installed near ferrite current transformer (CT) at accelerator, main amplifier with scheme for suppression of low-frequency inducings and ADC installed in CAMAC crate in accelerator control room. Working out amplifying tract of CT we paid attention to decreasing of level of circuit noises and external inducings [5]. In system "CT - amplifying tract" it was carried out optimization based on the criterion of signal/noise (S/N) maximum ratio. As result

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of this investigation it was found maximum S/N at number of turns of CT equal 170. The level of noise corresponds 80 nA of beam current. Existing software for BCT system is directed to subtraction of background, amplitude analysis of current pulses and getting some quantitative information for amplitude spectra (histograms).

3.3 Fast Beam Parameter Measurement System

FBPM system can measure a series of proton beam profiles with time interval between adjacent profiles equal $1,4\mu s$ and more. The measurements of beam current can be done within the same time interval by BCT system with separate fast ADC. Simplified scheme of system is given in Fig. 3 and consists of two main parts:

- Head part, i.e. complex of equipment placed near accelerator;
- Equipment placed in control room of accelerator.

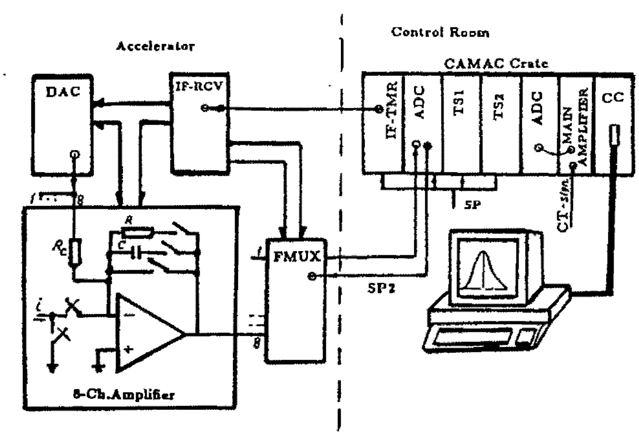

Figure 3: Simplified scheme of fast beam parameter measurement system.

Let's consider the structure and work of the main elements of the head part. Signals from MWC pass through 8-channel matching amplifier with switched gain factor and mode of work. In tuning mode amplifier works as linear amplifier, in exploitation mode it works as charge sensitive amplifier with gated input. In tuning mode signals enter the fast multiplexer (FMUX) which selects and holds time samples of beam profiles and takes out them in consecutive order to the cable leading to fast ADC. ADC – FMUX synchronization is provided by series of pulses (SP2) from ADC. Besides these modules head part contains also DAC and interface-receiver (IF-RCV), which are intended for synchronization, calibration and switching of the work mode.

Part of the system placed in control room of accelerator, consists of microcomputer and five modules (fast ADC, two timer-synchronizators (TS1 and TS2), interface-transmitter (IF-TMR) and crate-controller (CC)), placed in CAMAC crate. Module ADC has digital memory. This module makes digitizing of signals and then memorizes received information about the magnitudes of signals for subsequent reading them into computer memory. Module TS1 is intended for time attaching of the beginning of program running to synchronization pulse (SP) of accelerator. Let's consider structure and work of the part of complex which permits to carry out calibration and linearization of signal transmission tracts. This part of complex includes DAC, two interfaces (IF-TMR and IF-RCV) and TS2. The base of calibration algorithm consists in feeding of rectangular pulse from DAC to all inputs of matching amplifier. As DAC should be placed near matching amplifier, then transmission of digital code from computer to DAC is organized by modules IF-TMR and IF-RCV. Module IF-TMR provides recoding of parallel code of calibration pulse amplitude to serial code for transmission through the cable. Interface IF-RCV makes inverse transformation. Besides that module IF-TMR transmits special code words needful for time attaching of calibration pulses to multiplexer synchronization. Main stage of calibration is carried out when there are no beam current signals on MWC (for example, when MWC is taken out of beam) and consists in making up the work table of correspondence between DAC codes and codes being read from ADC memory. For this purpose it is set consecutively a few tens of DAC amplitudes with equal intervals between them. When measuring profile, inverse transformation is carried out. This permits to decrease considerably influence of following factors on final results of measurements:

1) spread of transmission coefficients of the channels;
2) non-linearity of tracts;
3) constant low-frequency and impulse inducings.

Besides that system permits to control any change of these factors directly in process of measurement. With this purpose in module IF-TMR it is organized starting of second sync pulse delayed from SP by module TS2 for the time sufficient for reading of all information from ADC memory to computer; and to DAC it is transmitted code of amplitude of verifying pulse and command for its forming. Thus, it is fed additional verifying pulse of known amplitude to calibration input of matching amplifier in every period between beam pulses, and it is started multiplexer, ADC and program for reading of response information to the computer memory. Result is compared with table (created at the beginning of measurement session with using of second sync pulse) and then is led out to videoterminal screen. It permits operator to decide whether it is needed repetition of the measurement because of some accidental momentary noise influence on the system (or maybe carrying out of new cycle of system calibration because of changed conditions of system work). If we are satisfied by test results then we convert, in accordance with work table, output values of ADC to corresponding input values of DAC. Because table is got only in finite number of points, then we need linear interpolation. After converting

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the array of output ADC values to equivalent DAC values we normalize result array on maximum value and lead out information in form of profiles. Then we either repeat cycle of measurements or go out of program.

Results of bench test measurements

System was tested on the stand. To all 8 inputs of system it was fed the same rectangular pulse. Following tests were carried out:

1) *Comparison of profiles which were got without calibration table and with table.* In both cases it was fed signal equal the half of maximum input signal. Without table we had spread of profile top of 20...30%, then with table 2...3%.

2) *Measurement at different speed of counting.* That is to say it was carried out measurements when varying the scanning time between multiplexer channels from some t_0 to t_{min}. It was got amplitude spectra (histograms) of output signal at different speed of counting. Results showed, that decreasing of scanning time less than 175 ns, which corresponds to the time of writing of one profile 1.4μs , gives rise of equipment errors because of limited speed of writing to ADC memory.

3) *Temperature drift.* It was received amplitude spectra of output signal in some time interval of system running. These measurements indicate that at room temperature one can work with the system without re-calibration during several hours not distorting measurement results.

4) *System linearity.* Research of linearity indicates that distortions are less than ±1%.

5) *Measurements with slow and fast inducings.* It was carried out measurements in conditions when slow inducing makes up approximately 8 % of signal amplitude, and fast local inducing makes up about 50 % of signal amplitude. Note, that given inducings were stable in time. Under these conditions due to calibration with the same strays we could avoid their influence and achieve rectangular profile with spread of top about 2...3%.

FBPM system is preparing now for installation on the accelerator with new measurement assembly.

4 Beam results

Simple profile measurement system and beam current transformer system were tested on proton beam transfer channel of the MMF Linac between injector and first accelerating resonator. MWC was installed perpendicularly to beam axis. Multiplexer was placed at the distance of ≈ 1 m from transfer channel. Information about shape and amplitude of pulse beam current was got with the help of our current transformer and BCT system. Serviceability of system was tested by introducing of collimator into channel at the distance of ≈ 0.8 m from CT and MWC. Changes of profiles after introducing of collimator (15 mm) is shown in Fig. 4 . Introducing of collimator decreases as signal amplitude as profile width. At pulse proton current

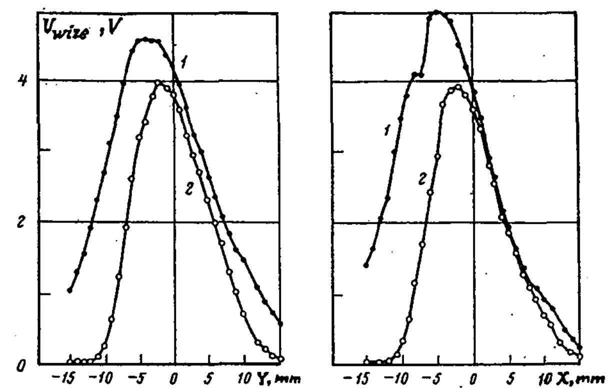

Figure 4: Beam profile change after introducing of collimator: 1)without, 2)with collimator.

≈ 120 mA, pulse duration ≈ 70μs the amplitude of signal on central wire was a few Volts and inducing signals were not more than 2 ADC channels (20 mV). Stability of beam current was measured by BCT. Pulse current shapes that were got by BCT system had more details than ones from usual current transformer monitor at the transfer channel. The inducings, that were measured in BCT tract, had maximum value 0.2% of usual pulse current magnitude in transfer channel.

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