The Transients in Linac and the Beam Fast Measuring System

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Abstract

The transients in Linac can be divided into two classes - static and electrodynamic. First ones of them are connected with the residual gas ionization in the accelerating channel. The electrodynamic transients are connected with the excitation of all eigen modes of cavity and the distortion of the accelerating field. This distortion causes the changes of the beam parameters. The characteristic time of these transients depends on many parameters of accelerator. In particular it depends on vacuum and dispersive features of cavity and equals approximately 5-10 microseconds. In the case of the high intensity accelerator the transients can have the important significance. It is obvious for study of so fast processes we need the beam parameters measuring system, which could give possibility to carry out the measurements a few times faster than these processes. In this paper we discuss the measurement scheme and the automatic system for fast observation and investigation of beam parameters in two points: at 750 keV beam transportation line after 45° bending magnet and at 160 MeV line after 26° bending magnet. The comparison of experimental results with theoretical model is presented.

1 INTRODUCTION

Detailed investigation of parameters for every beam pulse [1] are extensively used for tuning MMF Linac and adjustment of 160 MeV beam at isotope production complex (IPC) of INR. For this purpose beam profiles are measured by multiwire secondary emission grid (MWG). Presentation of beam pulse profile evolution (BPPE) gives possibilities to estimate influence of many factors, such as phase mismatching of accelerating resonators of Linac, distortions of electromagnetic field due to the high order modes excitation in resonators, changing of RF fields due to beam loading. The first experience of measurements [2] gave new observations on instabilities of 750 keV transportation line beam. We have found, in particular, a few phenomena: slow variation in position of mass centre line during the beam pulse, sharp changing of beam position due to unknown reason during a few seconds, and beam profile variations concerned with breakdowns of high voltage in injector. These new possibilities appeared because new system has higher speed of data acquisition. Beam parameter evolution data can show distortions of accelerator tuning for one single pulse, and these fast measurements give foundation for deeper and faster analysis of wells of errors and for searching the way for correction of Linac regime. New system gives BPPE picture, time pulse form and total one pulse profile during 1 s while old wire scanner system shows profile after 300 s.

Signals from MWG [3] are received and treated through specialized set of modules and standard CAMAC modules. This complete set together with controlling computer can be considered as computerized cluster of low level in general architecture of accelerator control system, but now this system is used as separate device for Linac tuning and beam adjustment.

Criterion of information detailing is taken being attached not only to speed of ADC and computer, but mainly to physical processes and their characteristic frequencies, which may be studied, not converting treating system into too expensive one. As 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 cut-off frequency of 160 kHz, then for observing influence of this loop on the beam, diagnostic system must be a few times faster.

2 PARAMETERS EVOLUTION MEASURING SYSTEM

Parameters evolution measuring system can measure a series of proton beam profiles for one single Linac beam pulse with time interval between adjacent profiles equal $1.4\mu s$ and more. Simplified scheme of system is given on Fig. 1 and consists of two main parts: 1) head part, i.e. complex of equipment placed near accelerator; 2) equipment placed in control room of accelerator. Signals from MWG pass through X and Y 8-channel matching amplifiers, which work as linear amplifiers. These signals enter two 8-channel Sample-and-Hold circuits with two multiplexers which select and hold time samples of X and Y beam profiles and takes out them in consecutive order to two cables leading to the 8-bit Flash-ADCs. ADC - FMUX synchronization is provided by series of pulses (SP2) from ADC. Head part contains also DAC and interface-receiver (IF-RCV), those 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 six modules (Flash-ADCs, timer-synchronizers (TS1 and TS2), interface-transmitter (IF-TMR) and crate-controller (CC)), placed in CAMAC crate. Flash-ADC has digital memory of 256 bytes. This module makes digitizing of signal with digitizing frequency

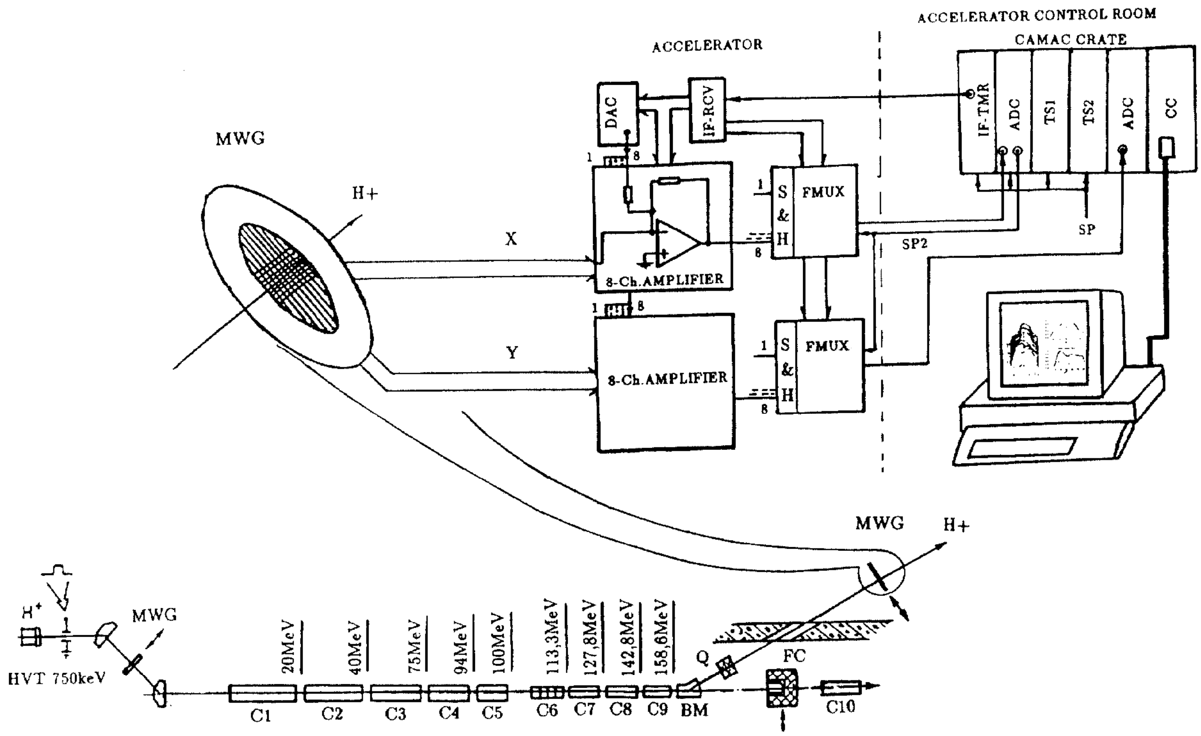

Figure 1: Simplified scheme of fast measuring system. C1...C10 - resonators; BM - bending magnet; FC - Faraday cup; HVT - high-voltage transformer; Q - quadrupole.

5 - 7 MHz and then memorizes received information about magnitudes of signals for subsequent reading them into computer memory.

Software consists of two parts: software bound up with calibration of measuring system, and software intended directly for beam profile measurement. Main stage of calibration is carried out when there are no beam current signals on MWG (for example, when MWG is removed from beam) and consists in making up the work table of correspondence between DAC codes (i.e. different amplitudes of calibration pulses) 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: from zero to amplitude corresponding maximum value at ADC input . When measuring beam profiles, inverse transformation is carried out, i.e. for ADC code it is put in accordance DAC code taking from table mentioned above. It permits to decrease considerably influence of following factors on final results of measurements: spread of transmission coefficients of the channels, non-linearity of tracts and constant impulse and low-frequency inducings.

All BPPE data are taken out as screen pictures with mountain view of BPPE which can be accompanied by beam pulse form and total profile of the same pulse. Beam pulse form is the result of summation over all points of separate profiles of BPPE with subsequent normalization. And total profile is the result of corresponding summation over all profiles of BPPE with subsequent normalization too. Mass centre line is given for total profile and mass centre evolution line is given for every BPPE figure.

3 BEAM RESULTS

From the outset profile measuring system was tested on 750 keV proton beam transportation channel and the next observations were got: beam pulse profile evolution (BPPE) in normal exploitation of transportation channel, BPPE transverse shift during a few seconds because of transportation line instability, BPPE changing a few seconds later of breakdown of injector, Fig. 2. It is most in-

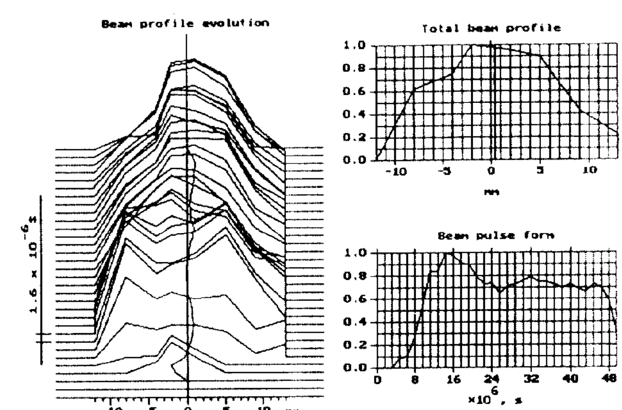

Figure 2.

teresting picture because vacuum is bad during some time after breakdown and head part of beam has oscillations, which damp slowly. These oscillations are excited in hydrogen plasma, which arises in transportation line at front of beam pulse, when gas pressure is higher than normal one. In principle, we observed the same phenomena which were described in paper [4]. But our device gives additional information. The charged hydrogen gas reduces the average space charge and therefore changes the advanced phase of beam in channel what causes the phase ellipse turn in both planes. Our BPPE picture gives possibility to observe not only dipole oscillation, but changing of the beam profile.

System testing at the IPC (beam energy - 160 MeV) for two-coordinate profile measurement permitted to observe some characteristic features of beam behaviour at this section and to tune accelerator very effectively by continuous beam control. MWG was installed at $\approx$ 8 m distance from bending magnet. Fig. 3 is the result of measurement for

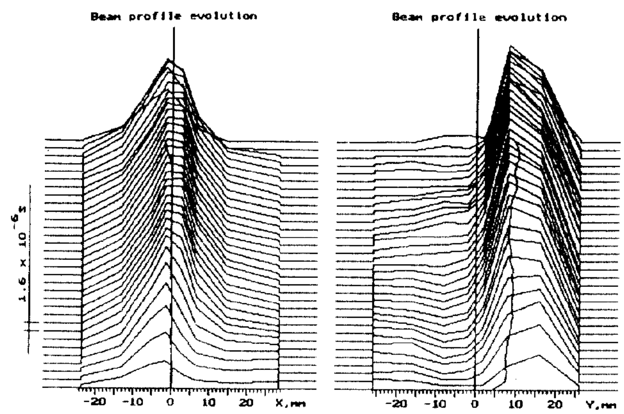

Figure 3.

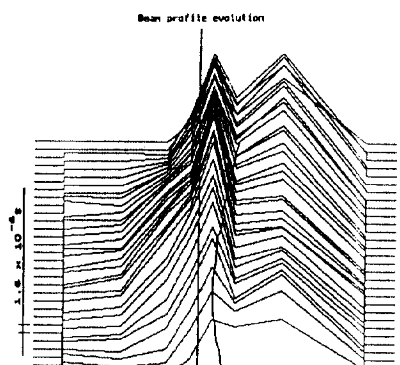

Figure 4.

two planes. It's easy to see that the beam is centered rather well in X-plane, i.e. it has got expected energy 160 MeV; in Y-plane the beam is displaced up. BPPE shown on Fig. 4 is measured at field level in bending magnet lower than nominal one. So profiles are displaced to the right side. It is interesting that profiles have two peaks. What does it mean? When the beam is injected into cavity, the generator has to give the additional power for the beam loading compensation. But any additional power excites all eigen modes of the cavity. One of them and the most powerful one has one oscillation of amplitude along the cavity and can be in the first order parametric resonance with the longitudinal motion. This resonance causes the splitting of the spectrum on two peaks. Since our device is placed after the bending magnet which gives the dispersion in the transverse plane, we should observe the splitting in X-plane too. Calculations, simulating the transient effect of beam, show, that in order to split effective transverse emittance during $1.6\mu s$ on two parts with distance between maxima 12.5 mm it is required the energy spread 0.178% of beam energy. It means the excitation of non-fundamental mode with amplitude 0.76% of fundamental one. From theoretical model of MMF Linac accelerating cavity it should be 0.6% .

4 CONCLUSION

Higher speed of data acquisition of new system ensures not only decreasing of MMF Linac tuning time and reducing effects of radiation induced by the beam, but besides that it provides physicists by qualitatively new information about processes which take place during beam pulse. For example, it is impossible to observe the shift of mass center line inside one pulse by means of system that gives only integral profile. The same can be said for case of profile peak splitting in 750 keV line. It could be appeared in integral profile picture as very small effect. Although for the high intensive beam accelerator this effect can play the significant role.

These observations are good stimulus for correcting of instabilities of 750 keV injector, transportation line and Linac. And the influences of these instabilities it is difficult to observe without fast automatic system which gives detailed picture of every beam pulse evolution.

5 REFERENCES

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