Computer System for Diagnostic of Electron Beam Using Transition Radiation

A.S.Chepurnov, A.S.Alimov, B.S.Ishkhanov, V.I.Shvedunov, P.L. Tkatchev

Institute of Nuclear Physics, Moscow State University.
119899, Moscow, Russia,
chas@rtm-cs.npi.msu.su, (095) 939-5659

Abstract.

A beam diagnostic system based on transition radiation analysis is a high-sensitive method for studying physical properties of the beam and adjusting of an accelerator. Optical transition radiation converted to a standard TV signal is analysed by the use of the unconventional computer based binary system of technical vision. It is possible to ensure beam diagnostics in real time due to the special hardware algorithms of image processing implemented in a video processor. This feature ensures cost effective solutions and simple software support. Data flows of digitised information are very compact and full of information. A diagnostic system is connected to the computer control system of a racetrack microtron injector - electron CW linac. Experimental results of the system application are described.

INTRODUCTION.

The optical transition radiation (OTR) effect [1-2] has gained general acceptance and can be used for many purposes involving beam diagnostics. Using the method based on trhe OTR effect one can receive all the necessary characteristics of a beam during the one cycle of OTR spot analysis:

- beam energy spread [3];
- beam positioning and beam profile [4];
- beam emittance [3, 5, 6];
- beam density and divergence [6].

The prime objective of our study was algorithms of image acquisition and processing, with the help of existing hardware. All parts of our image acquisition system are based on the LSI-11 compatible minicomputer. This computer type is widely used to-day for real time control of the injector of the Moscow CW racetrack microtron (RTM) [7, 8]. The system is connected with an IBM PC compatible computer (PC) via a standard interface. Graphical abilities of a PC are very suitable for man-machine interface support. The general scheme of the OTR analysis system is shown on figure 1.

The main feature of the computer control system is its control oriented architecture. Therefore, the presenting of a 3D image of the beam profile is an additional (not main) function of the image processing system. The main function of the system is "extraction" of digital indirect parameters corresponding to the beam properties. These parameters are used for closing feedback loops in the main control system to adjust output characteristics of the accelerator beam in real time.

Of course, in some operational modes of an accelerator it is very useful to observe an image of the beam in a way suitable for an operator. The operator could handle an overall image of the beam and "extract" simultaneously many parameters from the beam image, but the time of processing an image by an operator is not less than few seconds. But the question of adequate interpretation is very difficult and depends on the qualifications of the operator and the quality of the image restoring process.

The standard frequency of frames in normal TV signals is 50 Hz. Therefore, every 20 ms it is possible to get initial data for control algorithms for accelerator adjustments. In special applications when the beam has a pulsed nature with a frequency of more than 50 Hz, non-standard (higher) frequencies of frames could be used.

Commercially available frame grabbers are image oriented; they are oriented on the functional transformation, recording or storing of the whole frame. The algorithm of image processing for control application should be different. The main purpose of image processing for control is extracting a few digital parameters reflecting beam characteristics that could be used for digital closing of feedback loops.

The most simple example is the application of adjusting the electron optic system on the basis of the XY position of the beam OTR spot. XY coordinates of the beam spot center of gravity are only two numbers, and could be received as a result of a direct image processing system operation.

IMAGE PROCESSING HARDWARE.

OTR is converted to standard TV signals with the help of a TV camera. The image with the spot of OTR is stored and processed in an image acquisition board during the time of the next half-frame. A binary digitising system is used. A single bit sampling level could be set in a range of up to 256 levels of image brightness individually for every frame. The video processor unit supports in silicon the functions of square measurement, contouring, search on a raster and other special digital image processing functions. It is possible to realise beam diagnostics in real time due to features of the image acquisition board. Only necessary and useful data are transmitted to the control system, presented to operator and stored. The output data could be received in concrete beam parameters (size and position for example).

The hardware features ensure cost effective solutions and simple software support.

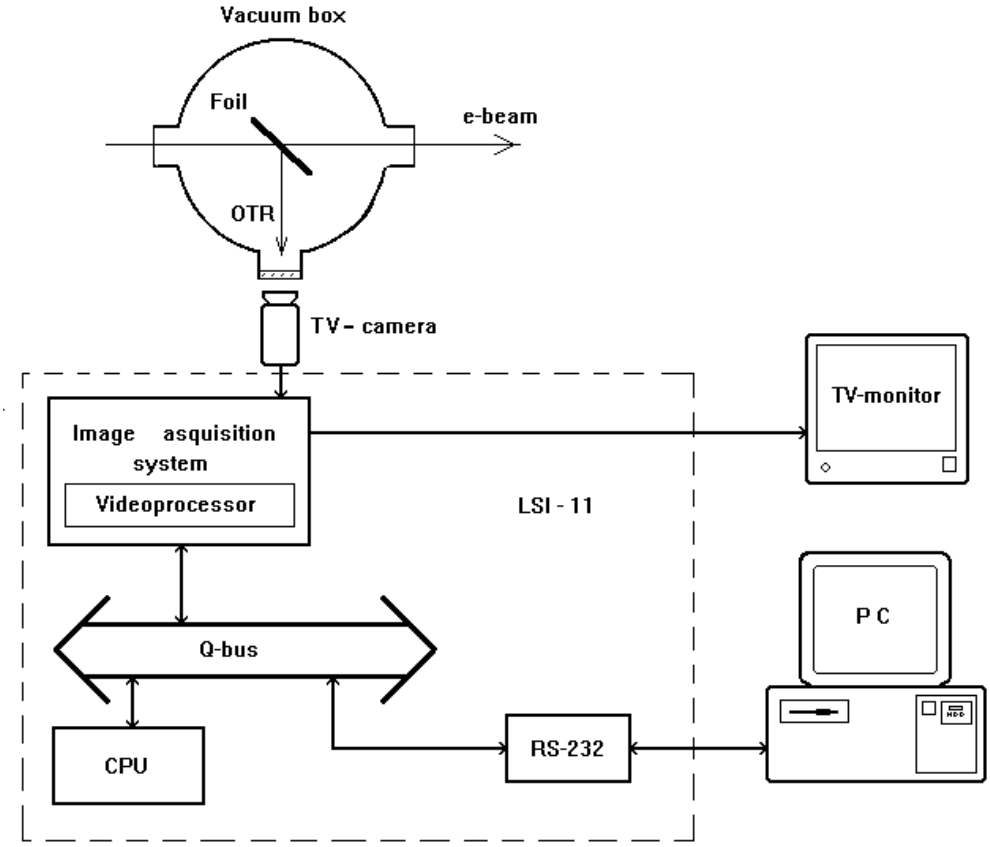

Figure 1. General scheme of OTR analysis system.

FIRST EXPERIMENTAL RESULTS.

The system has been used for studying an effect of the coupling slots on beam dynamics in the accelerating structure of RTM. This effect is explained by the transverse magnetic field excited on the axis of coupling cells and providing intercell coupling. Methods to compensate the coupling slot effect with external magnetic fields have been suggested [9]. For the exact measurements of the beam centre of gravity position and current distribution the method of OTR analysis has been used. At the axis of the beam 9 micron Al foil was placed at 45^{o}.

Standard TV signals from a black and white CCD camera with a 14:1 magnification objective were analysed by a computer system. An example of a 20 serial frame 3D current distribution of the beam is presented in figure 2.

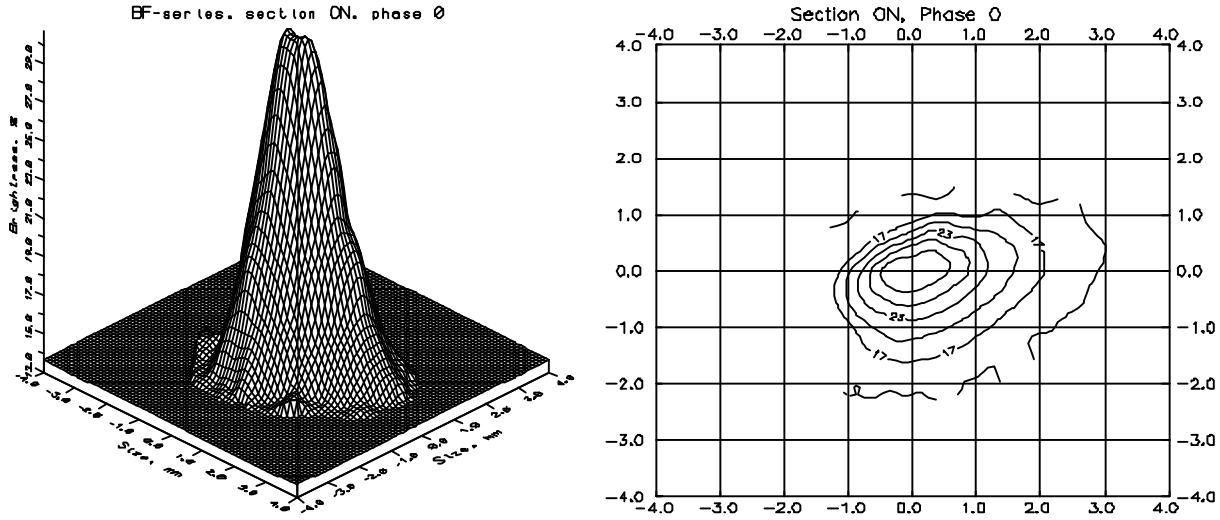

Figure 2. Restored 3D current distribution of the beam measured by means of OTR method.

IN THE FORESEEABLE FUTURE.

We are faced now with the problem of determining the accuracy of our measurement system carefully. The tasks of analog to digital channel linearization and increasing of the effective range and signal to noise ratio of the TV signal should be studied.

The image acquisition and processing algorithms will be implemented in a special hardware device based on modern technologies - digital signal processor and, soon FPGA. After the complete check-out a standard fieldbus interface (MIL-STD 1553B) will be added for fast connection with main computer control system of the accelerator, a system that is under construction now [10].

REFERENCES.

[1] I.Franc and V.Ginzburg, J.Phys. USSR 9, 353 (1945).

[2] L.Wartski, S.Roland, J.Lassale, M.Bolore and G.Filippi, J.Appl.Phys., vol. 46, No. 8, 3644 (1975).

[3] R.Chehad, M.Taurigna, G.Bienvenu, Beam Emittance Determination Using Optical Transition Radiation. Proceedings of the European Particle Accelerators Conference, 1977 pp.1139-1141.

[4] L.Wartsky et. al. Beam Diagnoctic Using Tramsitiom Radiation Produced by a 100 MeV Electron Beam. IEEE, Trans. Nucl. Sci, vol. 20, No. 5, 544 (1973).

[5] R.B.Florito, D.W.Rule, S.G.Iversen et al. Optical Transition Radiation Diagnostic for Low Emittance, High Energy, Charged Particle Beams, Proceedings of the European Particle Accelerators Conference, 1988. pp.1078-1080.

[6] S.G.Iversen, J.S.Ladish et. al. Charged Particle Beam Divergence Measurements Using Transition Radiation. IEEE CH2387-9/87/0000-0573.

[7] A.S.Alimov, V.I.Shvedunov, A.S.Chepurnov, O.V.Chubarov, et. al. Performance of the 6 MeV injector for the Moscow racetrack microtron. Nucl. Instr. and Meth. in Phys. Res., 1993, A326, pp.243-250.

[8] A.S.Chepurnov, I.V.Gribov et. al., Moscow University Race-Track Microtron Control System: Ideas and Developments //Proc. Int. Conf. on Accelerator and Large Experimental Physics Control Systems (Tsukuba, Japan, KEK, 11-15 Nov.1991.) Tsukuba, KEK, 1993, pp.140-142.

[9] V.I.Shvedunov, A.S.Alimov, A.S.Chepurnov et. al. Effect of Coupling Slots on Beam Dynamics in Accelerator Structure of Moscow CW RTM //Proceedings of the 1995 Particle Accelerator Conference, Dallas, USA, to be published.

[10] A.S.Chepurnov, A.A.Dorochin, K.A.Gudkov, V.E.Mnuskin, A.V.Shumakov. Family of smart devices on the base of DSP for Accelerator Control. (In these Proceedings).