FAST DATA-ACQUISITION SYSTEM FOR THE BEAM-ENERGY-SPREAD-MONITOR

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Abstract

A non-destructive beam-energy-spread monitor (ESM) using multi-stripline electrodes has been developed in order to measure and control the energy spread of a single-bunch electron beam. In the KEK injector linac, the non-destructive ESM has been installed at an 180-degree arc section with a beam energy of 1.7-GeV. The data-acquisition system of ESM was developed for pulse-by-pulse measurement. This system works well and is used for a daily operation. In this paper, we will present this DAQ system in detail.

INTRODUCTION

The KEK linac injects electrons and positrons into four different rings (PF, PF-AR, KEKB-HER and KEKB-LER). In a daily operation, a continuous beam tunning is very important for keeping the beam injection rate high. In the KEK linac, a screen monitor has been used as an ESM. However, the beam injection cannot be carried out during the beam measurement using a screen monitor since it is a destructive beam monitor. To realize the continuous injection, we have developed and installed the non-destructive ESM [1]. To acquire and process the analogue signal from ESM, the high-performance DAQ system is also needed. The most important requirement is a high-reliability for the long-term running.

DATA ACQUISITION SYSTEM

General Description

In the KEK linac, 90 strip-line-type beam-position-monitors (BPMs) with 4-electrode have been already installed and used stably for a daily operation [2]. Its DAQ system consists of 19 oscilloscopes, 19 VME computers and several server computers (hp Tru64 UNIX) [3]. The waveform digitized by an oscilloscope is sent to a VME computer via GPIB. After that, a VME computer translates the voltage data to the beam position and beam charge data. The calculated data is sent to a shared memory located in a server computer. Using this shared memory, many application programs can obtain the beam position and charge data. The data taking speed of the oscilloscope used in this ordinary system is not very high, and it cannot get the data in 50-Hz. Since the ESM aimed to be used for a fast beam-energy-spread feedback system, its DAQ system was developed independently of ordinary DAQ system. Schematic drawing of DAQ system is shown in Fig. 1.

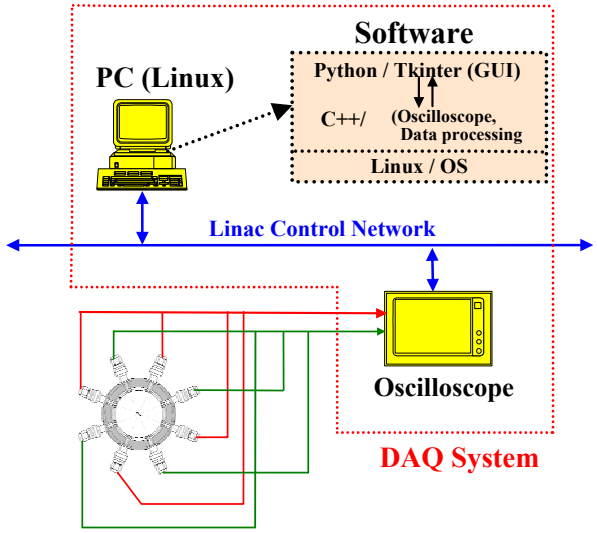


Fig. 1: Schematic drawing of DAQ system.It consists of a PC/Linux-based and a fast digital oscilloscope (LeCroy wavepro-950).

Hardware

DAQ system developed here consists of a digital oscilloscope and a PC/Linux-based. Any other analogue and digital circuit is not used. Such simple system setup can enhance the system reliability very much.

The eight signals from the ESM are divided by two signal groups alternately (2x4 signals). The four signals of each signal group are sent directly to a signal combiner through 35-m-long coaxial cables with suitable delay lines, which are required to avoid a superposition of the analogue signals. The two combined signals out of the signal combiners are directly connected to the digital oscilloscope. The trigger pulses synchronized with the beam are provided to the oscilloscopes at a maximum rate of 50-Hz cycle. This rate is applicable for communication between the PC and the oscilloscope through an ethernet. The PC receives the digitized waveform from the oscilloscope, extracts the eight-pickup voltages, and calculates the beam positions, charge and the multipole moments in 50-Hz via linac control network. It is even possible to observe two beam bunches separated 96-ns in an rf pulse. In a practical operation, every average over last 50 data is recorded into a log file. Using this log file, the analyzed data are displayed on any X terminals through a trend display software.

To evaluate the system performance, the data acquisition speed from an oscilloscope to a PC was

measured. Its result is shown in Fig. 2. In this test, two channels of an oscilloscope were simultaneously measured with 125-ps time resolution (8-GS/sec). For single bunch operation, a signal width from ESM is approximately 50-ns. Using a signal combiner, one oscilloscope can operate about ten ESMs up to 50-Hz operation. For two-bunch operation, one oscilloscope can operate only two ESMs since a signal width is about 200-ns with 100-ns bunch interval.

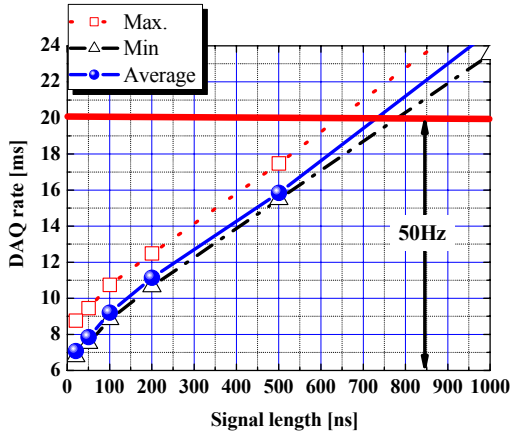


Fig. 2: Result of data acquisition speed. Square (red), triangle (black) and circle (blue) mean maximum, minimum and average data acquisition time.

Software

Software should work stably with high data taking repetition. In addition to that, easy modification and extension of the software is strongly needed. For these reasons, DAQ software was developed under PC/Linux. The C++ was used for the main routine, which treats to control an oscilloscope, transfer the data to PC, calculate the energy spread and store data into a log file. The reasons for using C++ are as follows:

(1) High execution speed (compiler language)
(2) High reusability (Object-Oriented language)
(3) STL (standard template library) can be used.

In the practical operation, all signal pulses (up to 50-Hz) are digitized, and the voltage amplitudes are calculated. Using this amplitude, we can calculate the beam positions (horizontal and vertical) and the energy spreads of each bunch. This software continues storing the data including its standard deviation into a log file during beam operation.

Python language is used for a graphical user interface (GUI) [4]. Python is an object oriented script language and it can use a wealth Tk GUI component via Tkinter module. Python-Mega-Widget (PMW) [5] and Tk-Interface-eXtension) [6] can also used for easy GUI construction. It can reduce the consumed time for the implement of a complicated GUI. In addition, we can use the numerical calculation packages for easy data processing [7]. One example of software GUI is shown in Fig. 3. In this case, upper and lower plot mean the measured data of single bunch and two-bunch operation respectively. In the lower plot, red and green dot show the energy spread of 1st and 2nd bunch beam respectively. Using this software, the energy spread can be always watched. Before the extreme deterioration of energy spread, we can adjust the beam condition in order to avoid a decrease of the beam transmission rate.

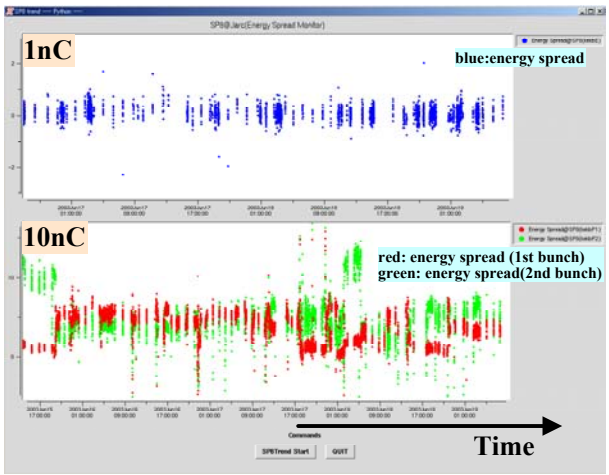
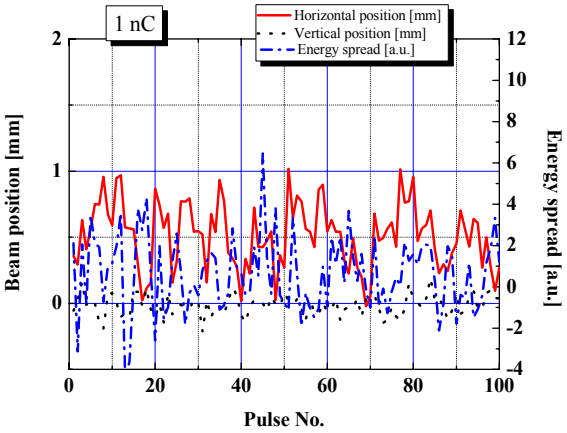


Fig. 3: Software GUI

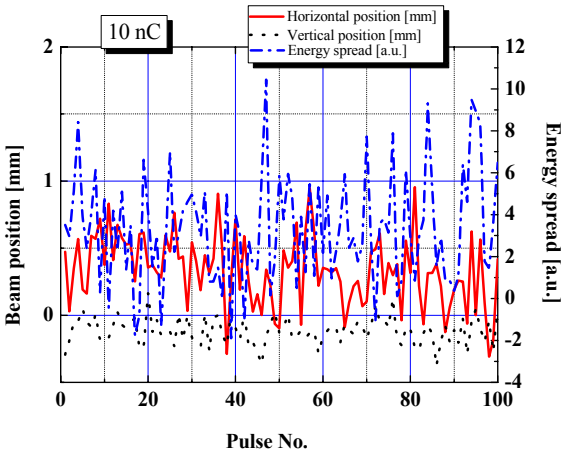
BEAM TEST

Pulse-by-Pulse Measurement

Most advantage point of this DAQ system is able to measure every data up to 50-Hz beam repetition. We measured the pulse-by-pulse variation of the beam-energy spread for 1-nC single bunch and 10-nC two-bunch mode. In this beam test, a series of 100-pulse beam was measured. The measured data of 1-nC and 10-nC mode are shown in Fig. 4-(a) and (b) respectively. In this figure, solid (red), dotted (black) and broken (blue) lines mean horizontal, vertical beam positions and energy spread, respectively. A standard deviation of this pulse-by-pulse fluctuation is summarized in Table 1. Its result shows that the variation of energy spread increases as the beam charge increases. It means that the beam-energy spread due to the beam loading increases as the beam charge increases.



(a) 1-nC mode



(b) 10-nC mode

Fig. 4: Result of pulse-by-pulse measurement. (a) and (b) show the result of 1-nC (single bunch) and 10-nC (two-bunch) operation modes respectively. Solid (red), dotted (black) and broken (blue) lines mean horizontal, vertical beam positions and energy spread, respectively.

Table 1: Variation of energy spread

Standard diviation of beam charge	1nC	10nC	Magnification (10nC/1nC)
Horizontal position [mm]	0.247	0.262	1.063
Vertical position [mm]	0.077	0.101	1.32
Energy spread [a.u.]	1.800	2.603	1.446

Long Term Measurement

This DAQ system has been used for a daily operation of KEK linac since Feb. of 2003. It has works stably without any trouble until now. Figure 5 shows the result of the two-bunch energy-spread variation during 20-days. In this figure, filled circle (blue) and open circle (red) show the energy spread of 1st and 2nd bunch respectively. It turns out that such long-term variation correlates with the drift of the sub-booster klystron phase. Therefore, controlling the sub-booster klystron phase can perform the energy-spread feedback.

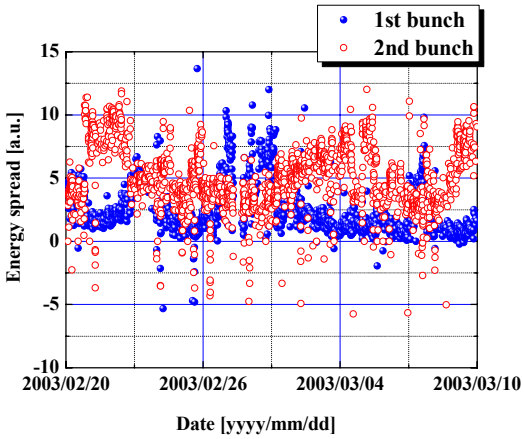


Fig. 5: Result of long-term mesasurement. Filled circle (blue) and open circle (red) show the energy spread of 1st and 2nd bunch respectively.

CONCLUSIONS

The fast and stable DAQ system was developed for the non-destructive ESM and used for a daily operation. Simple system setup consisting of an oscilloscope and a Linux/PC can realize a high reliability, which is strongly needed for a practical beam operation. It can also realize the two-bunch simultaneous measurement up to 50-Hz beam repetition. The beam-energy-spread feedback using this DAQ system is under development, and its result will be presented in the elsewhere.

REFERENCES

[1] T. Suwada, et al., “Nondestructive beam energy-spread monitor using multi-strip-line electrodes”, Phys. Rev. ST Accel. Beams 6, 032801 (2003).
[2] T. Suwada, et al., “Stripline-type beam-position-monitor system for single-bunch electron/positron beams”, Nucl. Instrum. & Methods. A 440 No.2 (2000) pp.307-319.
[3] N. Kamikubota, et al., “Data Acquisition of Beam-Position Monitors for the KEKB Injector-Linac”, Proceedings of ICALEPCS’99, Trieste, Italy, October 4-8, pp.217-219 (1999).
[4] http://www.python.org/
[5] http://pmw.sourceforge.net/
[6] http://tix.sourceforge.net/
[7] http://www.pfdubois.com/numpy/