DIAGNOSTIC SYSTEM OF LONGITUDINAL PROTON BEAM DYNAMICS IN HERA

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Abstract

A diagnostic system for longitudinal beam dynamics [1], which provides real time measurements of a single-proton bunch as well as multiple-proton bunches (up to 180) for the HERA [2] accelerator, has recently been developed. The measured data are stored in VME based 10Mhz fast ADC modules and following a trigger are collected in Linux VME PC memory, where they are further compressed and copied to the dCache [3] system for post mortem analysis. Relatively huge amounts of data, typically 8 Mbytes per 10 seconds during beam ramping time, are collected. This results in about 8 GBytes of data each day. The front end PC's local disk keeps only recently collected data. An archive reader server program running in parallel, provides services for data analysis client programs, by accessing data in the front end PC's local disk and in the dCache. Detailed development issues for the data handling and presentation of the longitudinal proton beam parameters are described in this paper. In particular, we shall present a mechanism for dealing with large amount data in a homogeneous way. The software is based on the TINE [4] data-exchange protocol and uses ACOP [5] at the client-side for data acquisition and display.

INTRODUCTION

The HERA proton storage ring has 220 possible bunch positions 96 ns apart, 180 of which are occupied. During proton acceleration from 40 Gev to 920 Gev, one observes a strong increase in the emittance. The coherent oscillations of the proton beam during acceleration lead to an increase of the bunch length and a decrease of luminosity. In order to conserve the emittance, reduce the bunch length and increase general understanding one needs a new diagnostic system, which measures the longitudinal bunch length and phase of every bunch, and the transient and accelerating RF voltages of all cavities.

The most important parts of this system are: custom designed filters for measuring the 52MHz and 208 MHz Fourier components of the individual bunch shape, special timing modules for providing a clock and generating triggers, as well as the associated software data acquisition and analysis package.

HARDWARE CONPONENTS FOR FAST LONGITUDINAL DIAGNOSTIC AND FAST CAVITY DIAGNOSTICS

For data acquisition, a VME crate contains a VMIVME-7591 from VMIC, single board with IBM PC compatible Pentium processor based computer with 330 MHz, running LINUX 2.4 and a local IDE disk with 32 Gbytes of capacity for intermediate data storage. The raw data are sampled by five VME ADC boards, each containing eight ADC channels, with digital bandwidths of 10.6 MHz and an analog bandwidth of about 60 MHz. Each ADC module has 2 Mbytes of memory. A single VMEbus IndustryPack (IP) Digital carrier board, VIPC61 from SBS, is used to interface timing modules, with delay steps of 500 ps, to supply the ADC board with clock and trigger signals independently.

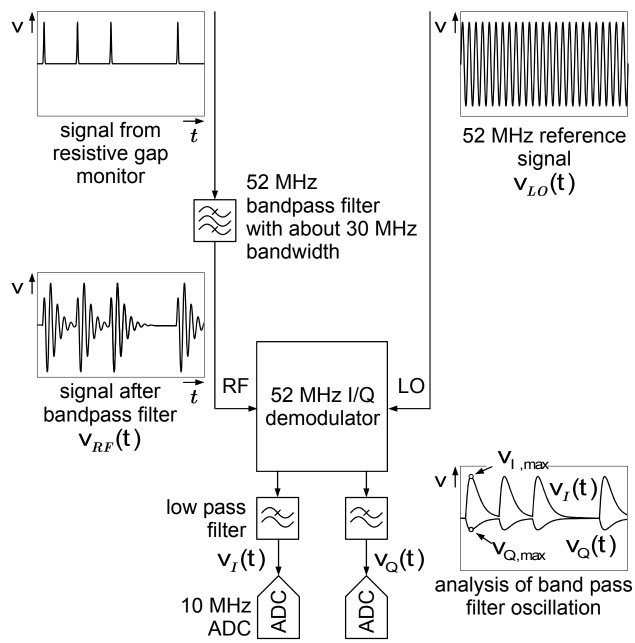

Figure 1:. Measurement principle

The bunch length and phase measurement consists of a resistive gap monitor with a time resolution of approximately 200ps, band pass filters and IQ demodulator. Both the signals of the gap monitor and the 52Mhz reference provide inputs for IQ modules. The fast ADC modules sample the real and imaginary parts after the demodulator. A selected single-proton bunch per revolution as well as multiple-proton bunches with defined intervals are independently sampled by two groups of ADCs. For HF cavity field diagnostics, duplex filters are used to separate accelerating voltage and the beam-loading transient. One IQ demodulator, two duplex filters and four ADC channels are connected to cavity pickup and reference signals for each cavity. Figure 1 shows the measurement principle of the phase and amplitude of the 52 MHz Fourier component of a single bunch signal, while Figure 2 is an overall view of the system.

The phase, length, and intensity of each single bunch are recorded within the time span with which subsequent bunches pass a resistive gap monitor. At the same time the system records RF transients in all six cavities as well. For the determination of multi-bunch oscillation, the ADC board is started several times per measurement cycle with an eligible number of samples prior to readout. Sampling all 220-bunch positions, separated by 96 ns, only every 104th revolution is a good compromise between time and frequency resolution for the observation of the oscillation (~40Hz).

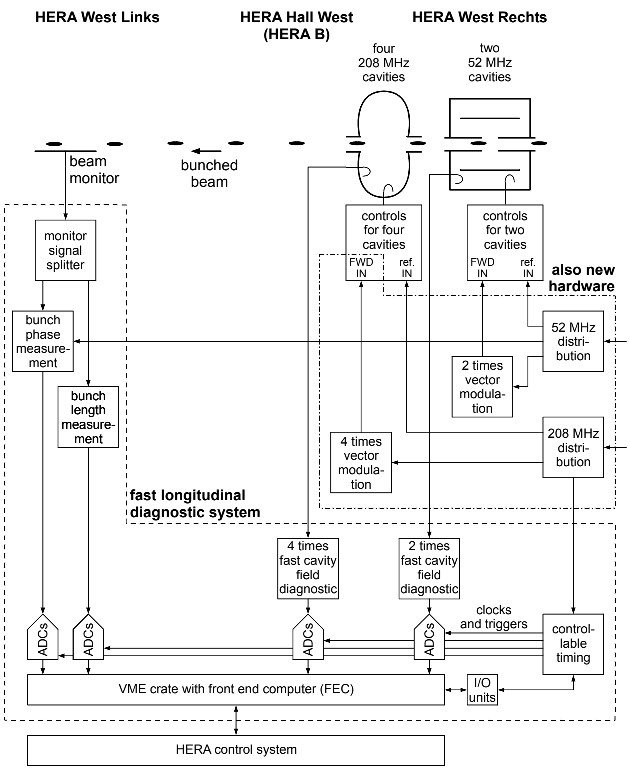

Figure 2: An overall view

DATA ACQISITION AND ARCHIVE SERVERS

In the VME CPU, two servers are running for data taking and archive reader. Another two chron-jobs are responsible for managing of local disk capacity and data archive to the dCache (a distributed storage management data caching system).

A normal PC running LINUX is used for handling the dCache archive data, to provide long-term post mortem data analysis.

Data Server

The software is written with multithreaded architecture. One-thread processes the user command, coming from clients, the other threads (each one responsible for one ADC card), upon interrupts, fetch ADC raw data, convert and store them to local disk. Several operation modes are defined for data taking, according to machine status and user requests, the server will set parameters to timing and ADC modules, via VME bus. The server has various links to other servers to get the current machine status. The local disk (32Gbytes) is, under normal condition, just enough for storing data for a few days.

For the measurement of 220 bunches with every 104th revolution, one set of data filled in the ADC memory takes half a second. The calculation power of the VME CPU used allows one record for all five ADC boards to be taken every 11 seconds (fast mode). This is the case during a ramp. Afterwards data are sampled every 3 minutes (slow mode).

Archive Server

The data archived by the data acquisition server, are stored as binary files with a Unix time stamp as the name and a type extension. One file contains converted ADC data, the related machine parameters and corresponding conversion parameters. This server scans and sorts files on the local disk, reads the data (according to user requested time periods), and returns data to its clients. As the archive server and the data acquisition server have the same interface, the same client program can trivially access data sets from both servers.

Through an exclusive 100Mbits/s network and the TINE data-exchange protocol, a tolerable access time is guaranteed for large amount of data transfer per call, typically half Mbytes.

Data Archive

File management consists of two background processes. One prevents an overrun of the local hard disk by deleting the oldest records when the disk is 90% full. The other combines and compresses data records in packages of about 600 Mbytes. These packages are in turn copied to the DESY tape system 'dCache' to ensure a long-term archive.

To avoid affecting the data collection threads, the data compression process only takes action when the data server is acquiring data in slow mode or is idle.

dCache Archive Server

A standard Linux PC is used as an interface to the dCache system. A second instance of the archive server software runs on this PC as well, allowing very long-term data retrieval. Additional functionality is planned for fetching and decompressing data records from the dCache system automatically. Applications can access live data via the data acquisition server, or archived data via either or both the archive server and the dCache archive server, by merely pointing to the desired server.

CONSOLE AND OFFLINE APPLICATIONS

A comfortable display and post mortem data analysis program, written with Visual Basic 6.0 and running on WINDOWS workstations was developed both for the control room and offices [6].

One difficulty was how to bring the large volume of information to the presentation level. To this end, the basic information (220 Kb) is presented as an 8-bit colour bitmap where deviations from average values of phase, length of bunches, RF Cavities transient and etc. are shown accordingly.

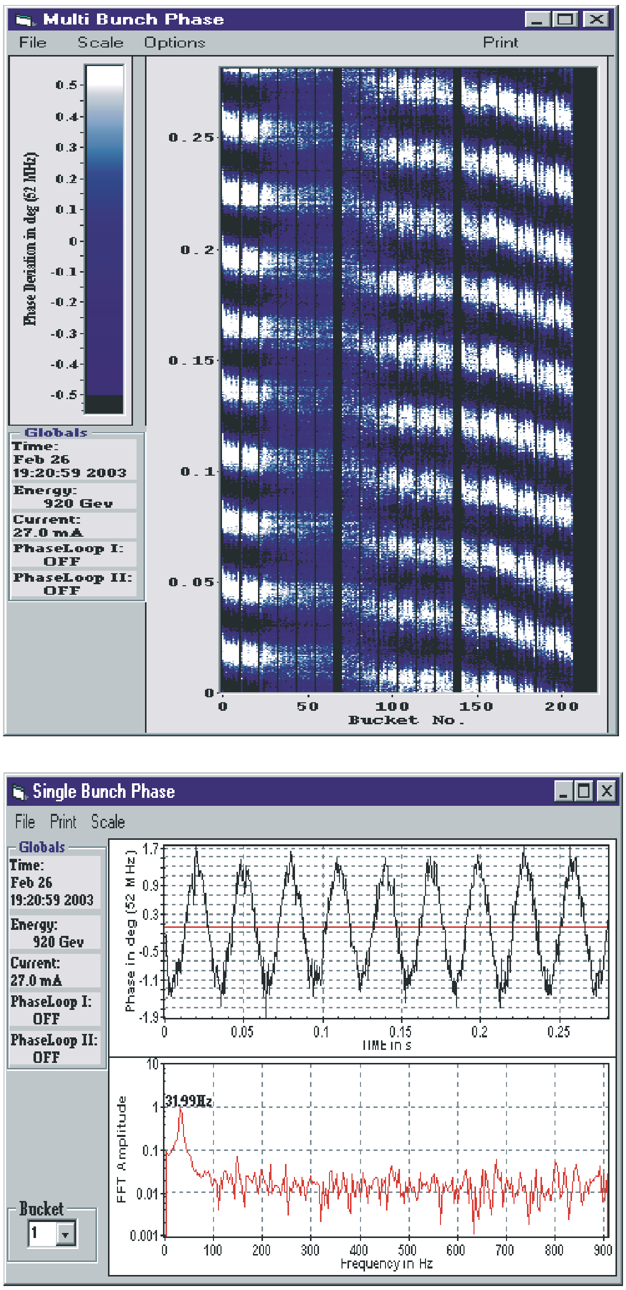

Figure 3: Multi and single bunch dipole oscillation

For the transformation of the information into a bitmap, the GDI32.lib library was used. For coordinate binding of the displayed information the scaling and zooming abilities of ACOP are used, whereby the picture bitmap is superimposed upon the ACOP graphic window. A similar superposition is used to bind digits to a colour-"palette".

The program has two operation modes. The live mode shows the newest data record while the archive mode allows one to select a period of archived data sets through a monthly calendar. There are more than 30 presentation forms for display and analysis, such as 'Multi Bunch Phase', 'Cavity transient', 'Phase Oscillation Modal analysis' and so on. A simple navigation possibility is implemented for searching for ramp start times. Various standard graphic features of the HERA control system have been implemented as well. Figure 3 shows an example of the application program.

CONCLUSIONS

The Fast Longitudinal Diagnostic system has become a standard tool for examination of the longitudinal stability in the HERA proton ring. The longitudinal coupled multi-bunch oscillation, beam loading voltage and accelerating voltage, can be routinely measured. Beam longitudinal behaviour and RF system can be analysed. This system provides necessary information for the design of a RF feed-forward and a coupled-bunch feed back system for the preservation of the longitudinal emittance.

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