CONTROL SYSTEM OF IPCR HEAVY ION LINAC

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ABSTRACT

The control system of IPCR heavy ion linac (RILAC) uses a mini-computer, HPIB and commercially available control/measurement processors, for the monitoring and adjustment of the parameters and devices of the accelerator.

INTRODUCTION

The IPCR heavy ion linac is designed to accelerate ions of every element. It consists of an injector with an ion source, six RF accelerattion cavities and many magnets for the beam transport. Fig. 1 shows the layout of the linac. The main feature of the linac is that the acceleration RF frequency can be adjusted between 17 and 45 MHz to get moderate acceleration field at the drift tube gaps independently of the accelerated ions. The maximum energy of the ions is 0.7 - 4 MeV/amu, depending on the frequency. This linac was completed in 1981 and has been used for various experiments since 1982.

Since the linac accelerates various ions at different frequencies, the number of the parameters to be controlled is large compared with an ordinary fixed-frequency linac and when the frequency, the charge and mass of the ions and the energy are changed, many parameters of the ion source, RF systems and beam transport systems should be changed.

In order to use the linac efficiently, the control system should be reliable so that the loss of beam time due to its failure is small, and helpful to reduce the time needed to start up the linac and change the acceleration conditions. In addition, the control system should be flexible enough to accommodate to possible future expansion and change in the accelerator system. A computer system was introduced to reduce the wiring between the linac and the control room, to get flexibility in the I/O and console configuration, to utilize accumulated data on the operation, to perform numerical calculations and to simplify control procedures.

At present, the computer is mainly used for the control of the magnet power supplies, the RF systems and some beam diagnostic devices. It sends the controlled devices digital commands to change the status in bits or 12bit words and set-point values for analog parameters and monitors the status and analog measurements.

HARDWARE

Computer

A block diagram of the hardware configuration of the control system is shown in Fig. 2. The computer is an HP 1000 system supplied by Yokogawa-Hewlett-Packard (YHP) with 160 kw of 16bit memory and a disc base real time operating system RTE IV-A. Peripheral devices are a 19.6MB disc, a magnetic tape, a CRT terminal for the system console, two CRT terminals for operator consoles and a serial printer. The IEEE-488 standard interface bus (HPIB) is used for the communication between the computer and I/O devices interfacing the linac equipments. The HPIB is extended with optical fibers for the communication between the computer and the accelerator vault, where the distance is larger than the maximum allowed length (20m) of the ordinary HPIB cable. The transfer rate is about 40kbyte/sec with the extenders.

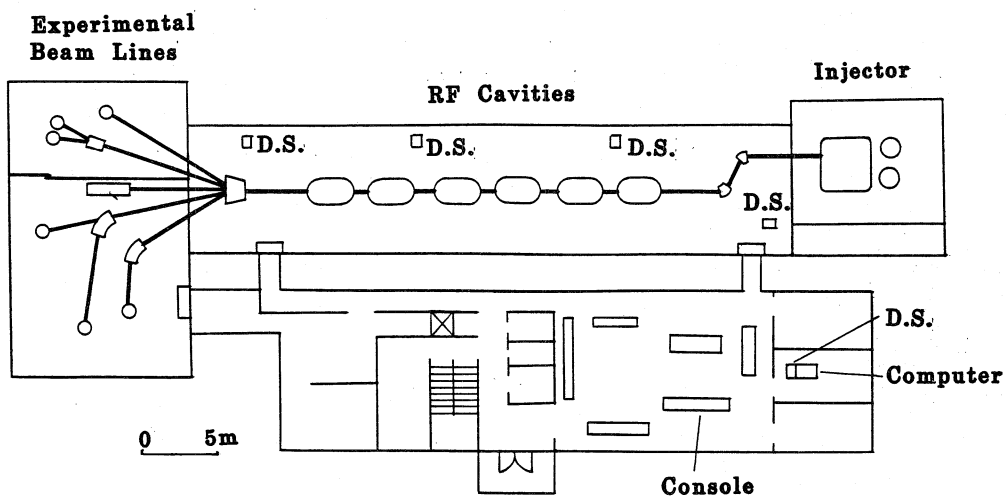

Fig. 1 Layout of IPCR heavy ion linac (RILAC). Data stations are shown as D.S. in this figure.

I/O Devices

Signal lines for the remote control and measurement of the linac devices are wired to one of five data stations, four in the accelerator vault and one in the computer room. The position of the stations are shown in Fig. 1. In each station, a control and measurement processor (HP2240/2241 supplied by YHP) is set for the interface to the controlled devices. It has a microprocessor, memory and up to eight circuit boards for the input and output of digital and analog signals. It accepts and stores a series of commands sent from the computer via the HPIB, performs the input and output operations, timing, scanning and self test independently to the computer and sends the results back to the computer. Standardized circuits for the signal conditioning are provided to convert, amplify and isolate the signals between the processor I/O boards and the controlled devices if necessary.

Portable Terminal

A portable terminal with a keyboard and indicators can be connected to the computer for the local and on-line operation, test and experiment of the devices in the accelerator vault. For the connection of the terminal, a twisted-pair serial data link cable with connectors is extended throughout the accelerator vault. This serial data link can be used as a back-up communication link in case of the fault of the fiber optic HPIB extenders.

Console

In the control room, there are racks for display panels and a operator console. The two CRT terminals for the operation, with keyboards and cassette tape units, are set in the console. One of the CRT terminals displays both characters and graphics whereas the other, characters only. These CRT terminals are used for both the linac operation and the

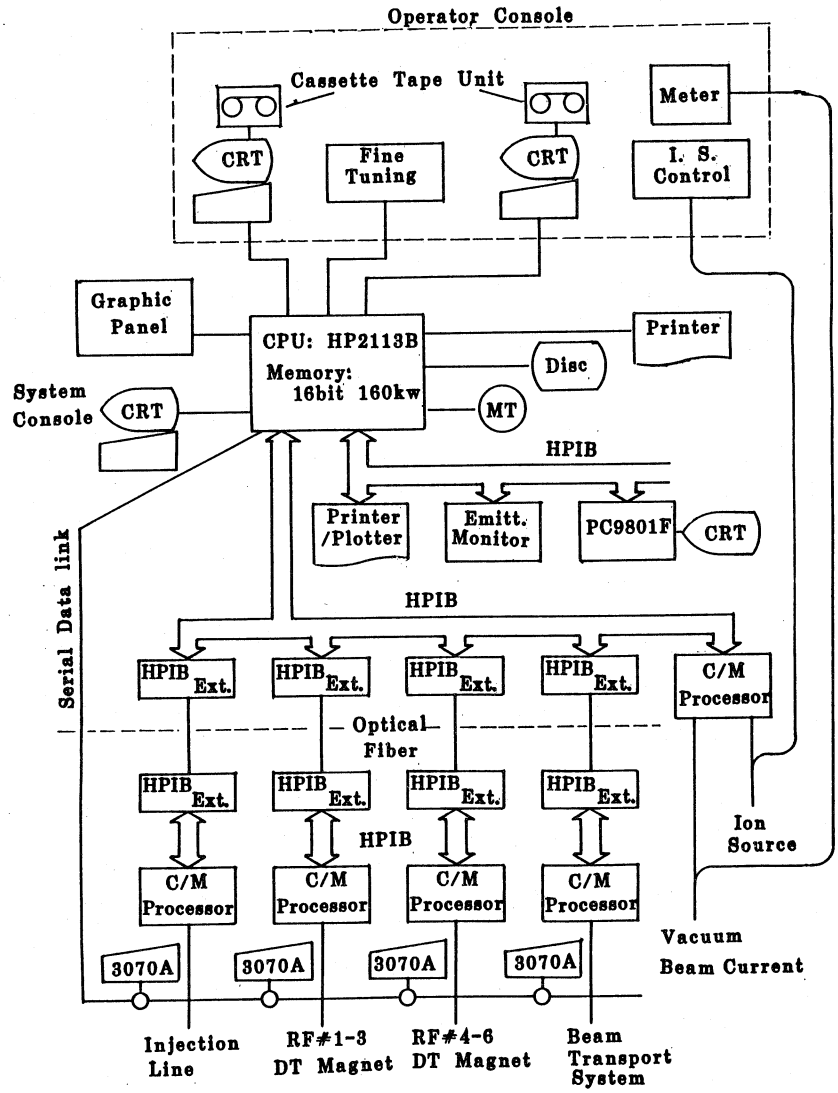

Fig. 2 Block diagram of control system based on HP1000 computer. HPIB Ext. denotes HP37203A HPIB extender which converts HPIB data to fiber optic serial data and vice versa. C/M processor denotes HP2240A/2241A control and measurement processor. 3070A denotes HP3070A portable terminal.

program development. A dedicated control device is installed in the console which is for fine tuning of up to three analog parameters by shaft encoders. The device has a microprocessor and is connected to the computer. The controlled parameters are allocated at the keyboard of the CRT terminal.

A personal computer NEC PC9801F is connected to the computer via the HPIB and works as a color graphic display to show the gross status of the linac. In case of failure in one of the equipments, it displays the equipment by changing the color and prints the time and cause of the failure.

Dedicated off-line control and display panels are provided in the console for the operation of the ion source, whereas the data of the ion source are also gathered by the computer. The status of the vacuum and the cooling system is displayed at the display panels.

Beam current and profile data are gathered and displayed by dedicated circuits independent of the computer and the result can be sent to the computer. A beam emittance monitor with microprocessors is connected to the HPIB and the computer numerically processes the gathered data and displays the result on the graphic CRT.

SOFTWARE

Operating system

In order to operate different parts of the linac with the computer in parallel, its operating system (OS) is required to allow concurrent and real time execution of different programs without conflict, communication between the programs, easy access to disc files and easy development of application programs. Because the linac is operated in a CW mode, the computer is not necessarily to respond to an external interrupt quickly. The RTE IV-A OS and the utility programs offer such functions, besides it fully supports the HPIB operation allowing the HPIB I/O with simple READ and WRITE statements of FORTRAN.

Application Programs

The application programs have been developed on the RTE IV-A OS, using the file management utility program. Most of the programs are written in FORTRAN IV but some for beam diagnosis are in assembler because it has to communicate with a microprocessor and to perform bit manipulation of the data words.

The application programs are for i) linac operation ii) linac device test, iii) calculation, iv) data base management and others.

The programs for the linac operation consists of tasks to set the acceleration conditions at the beginning of the operation, to operate the magnet currents and RF parameters interactively, to print out and store the linac data, to display the linac status and to alarm in case of failure based on the result of periodical total surveillance. Most of the tasks are scheduled by other task according to operator commands or scheduled periodically.

The programs for device test is scheduled by the operator when it is necessary to check the performance of individual linac device or front end I/O circuit of the control system. The device test can be done interactively either in the control room using the console CRT or at the controlled devices in the accelerator vault using the portable terminal.

Some programs have been developed to calculate accelerator parameters like ion source extraction voltage, injector and RF voltages or magnet currents, at a given acceleration condition. The calculation program is performed by request of the operators or scheduled by a program for the linac operation

The data of the controlled devices, parameters and the I/O devices are stored in disk files. Some programs are for the maintenance and modification of the data in the files. In case of changes in the linac equipments, the programs of the linac operation are not changed but the data in the files are modified.

OPERATION

At the beginning of operation, the operators input acceleration conditions like ion species, acceleration frequency and experimental beam line. They can select and read back data of linac parameters saved during past operations and reproduce that condition. It takes about a few hours to start up the accelerator and get the beam at the target.

In normal operation, the operators monitors the intensity, profile and position at different positions in the beam line, and control the equipments and parameters of the linac in order to optimize the beam condition. One of the CRT terminals at the console is mainly used for the RF system, and the other CRT terminal along with the fine tuning device for the magnet currents. The ion source parameters are adjusted at the dedicated off-line control panel. When the linac is very stable, it needs few adjustments of the parameters.

The computer can process some procedures like setting up the magnet power supplies of experimental beam line or restoration of RF power supplies after protection circuits shut them down. We are planning to automate the process to change the frequency.

FUTURE

In 1986, a post-stripper accelerator, a separated sector cyclotron (SSC) under construction, will be completed and the control system of the linac will become a part of the total control system of the whole accelerator complex. The present computer will be replaced by a new one which constitute a computer network. Details of the control system of the SSC will be given elsewhere.

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