A MICRO-PROCESSOR BASED MEASURING SYSTEM FOR CYCLOTRON*

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Abstract

For centralizing measuring parameters of cycloton, a micro-processor based automatic polling and data analising system was developed. Conditions set for the experiment and cyclotron operating parameters could be easily taken into the system, and then printed out or stored on to diskette for later use. All important parameters including beam intensity, profile and its axial position when entering and exiting slits of analyser could be continuously monitored.

System hardware and software and a step-motor driven scanning probe are briefly described.

Introduction

Cyclotron in the Institute of Nuclear Science and Technology, Sichuan University was put into operation in 1981. Over the years, the accelerator offered thausands hours of beam time to isotope production, apply physics research and varieties of low energy nuclear physics experiments. Accelerated ions includ H_2^+, α, and d. Beam intensity for deutron varies from nano ampres (measured at the exit of the analising magnet) to 300 micro ampres (at extraction radius)[1]. Since the different experiment requires its particular beam set with specific operation conditions, the parameter collection and analising is thus very fundamental task that operators shoud carry on. But unfortunately, the cyclotron in INST. is the sort of old designed version, not only the destributed pointer-type meter panels bring trouble to parameter measurement and data readout, but also the lack of instrumentation makes the beam intensity and profile monitoring uneasy. So a program of developing an auto polling system and enhancing instrumentation was planed a year before. Partial completed program described here is a microprocessor based AP system. The three major functions of the system are:

a. Cyclotron operation parameters automatic measuring, total 18 channels, include main magnetic field, Dee voltages, parameters of vacuum system, ion source and beam transport system.

b. Beam intensity and profile continuously monitoring, total 6 channels, it does data acquisition, real time scalling and on line data analising.

c. Recordes keeping and file handdling, except displaying and printing out the measuring results, the system could also save recordes onto diskette as a numbered file. Load and review the stored file could easily be done when off line with supported disk operating system.

System Hardware Configration

The AP system is mainly supported by a Apple-II plus micro computer, peripherial devices of which includes a 12 inch monochrome VDM, a SP-1000 charactor printer and two FD-55A type 5¼ inch floppy disk drivers. Shown in Fig-1 is block diagram of the system. All signals representing parameters are proper sampled and then hooked up to electronics NIM modules, where they will be amplifiered, filtered and scaled to certain range. Coded by the computer, any desired signal could be switched to a 12-bit A to D converter by the 8/64-channel multiplexer. Then cpu takes data via a parallel interface SY-6522 VIA.

For future system expansion, a 6522 compatible single board computer has been connected with main computer via a 2K-byte shared RAM block. The SBC later will be used as cyclotron ON/OFF control and setpoint adjustment.

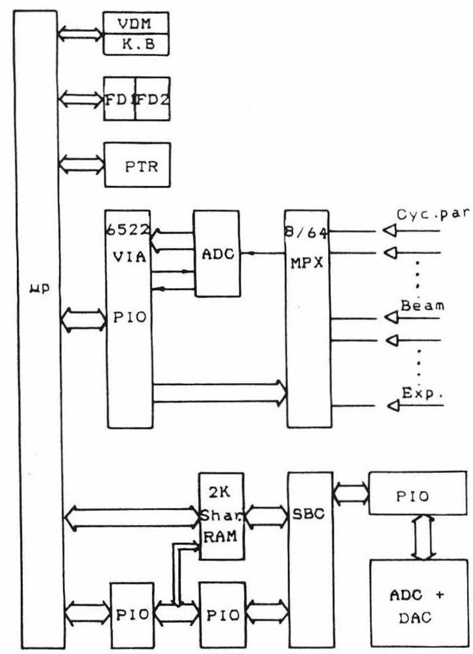

Fig-1. Block diagram of the AP system

Software Consideration

The system supervisor program is written in APPLESOFT BASIC high level language, the intepretor of which is ROM resident and DOS 3.3 operation system supported.

For easy use, so called operator friendly software is designed that man-machine interactive is possible at any level following upset tree shape structure. Different mode selecting is based on function choosing and condition setting, which are always explicitly listed on screen. Under the guidance of the instruction menu, operator can get desired choice simply by key striking. For later expanding the system to ON/OFF control and setpoint adjustment, this straitfoward software arrangement will make the cyclotron operation even simple and mistake avoiding.

Cooperated with the main supervisor program is the soft package consisting of many utility program and subroutines written in 6502 assembly language. When does monitoring, information about beam intensity along with time axis and profile in X-Y plane are regularly read into the system memories in responding the data acquisition interrupt request. At rest time, the system keeps doing on line data analising, such as beam integration, profile curve sweeping and beam axis position calculation or tracking.

Beam Profile Scanner

As part of the instrumentation enhancing program, a experimental thin probe beam scanner was built in order to help operator knowing the beam profile and X-Y axis center position right before entering the slit of the analising magnet, which is crucial for having as highest as possible beam intensity with required energy resolution.

Shown in Fig-2 is the schematic drawing of mechanical structure of the scanner head assembly. It is basically a flanged stainless steel vacuum chamber (Fig-3), mounted in it are X and Y direction rotation probes driven by X and Y step motors respectively. As a section of trasport pipe line, rotating probes will intercept beam in X and Y direction step by step under control of the motors.

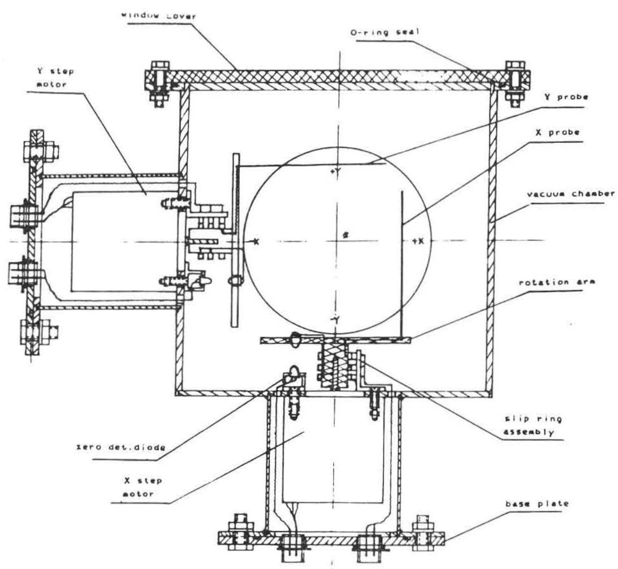

Fig-2. Mechanical details of the scanner assembly

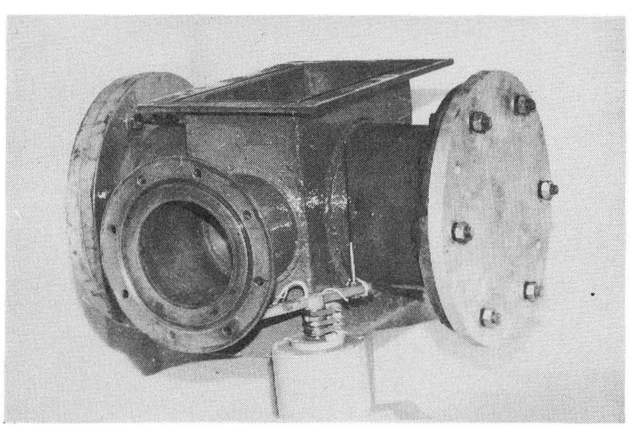

Fig-3. Scanner head vacuum chamber

Ions the X-probe picked up is proportional to the average beam intensity at certain X coordinate of the beam cross section within a short duration time T, that is:

$$\overline{q}_{xK}=\frac{1}{T}\int_0^T\int_{R\cdot\cos\frac{K\pi}{N}+r}^{R\cdot\cos\frac{K\pi}{N}-r}\sigma(x,t)\,dx\,dt$$

where $\overline{q}_{xK}$ is average charge the X-probe collected at kth step within time T, $\sigma(x,t)$ is space charge density the beam creats at x when time equals t, while R and r are radius of rotation arm and probe respectively, and N is the total steps in half cycle.

And so is the same for $\overline{q}_{yK}$ in Y direction:

$$\overline{q}_{yK}=\frac{1}{T}\int_0^T\int_{R\cdot\cos\frac{K\pi}{N}+r}^{R\cdot\cos\frac{K\pi}{N}-r}\sigma(y,t)\,dy\,dt$$

For our case, the maximum speed of the step motor is 800-3000 step/sec, and 1.5°/step. So the total steps for intercepting beam from 0° to 180° is N=180/1.5=120. The actual motor running speed will be selected according to RF modulation repetition frequency. Suppose that beam intensity is 5μA with 1ms pulse width and 10Hz repetition rate, then the average current of a probe 1mm in diameter gives out is proximately 100nA.

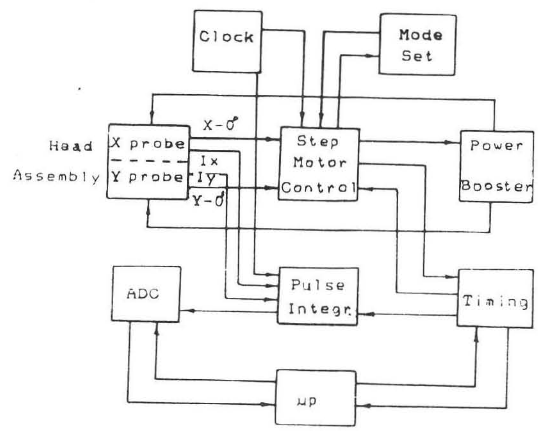

Fig-4. Circuit block diagram of the scanner

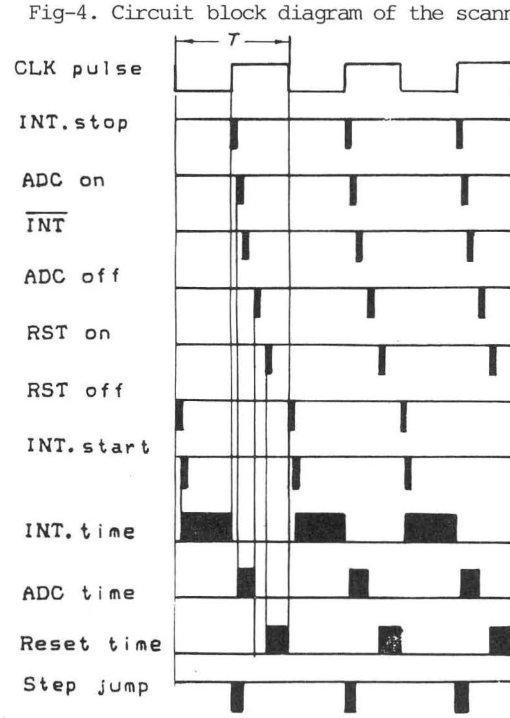

Fig-5. Timing and sequential pulses

The current will be brought to outside with the help of slip ring and then sent to the input port of a pulse integrator via coaxial cable. Block diagram of the electronics setup is shown in fig-4. Synchronized by clock pulse, the timing circuit will control the step jump and integration time, and then interrupt cpu to start A/D conversion and data reading. One complete scan will give 120 datum that corresponds to 120 steps, starting at 0° and ending at 180°. A zero-cross detecting photo diode will set the starting point while a counter pre-set to 120 will determine the end of the scan. As soon as one scan is over, the motor turns back with highest speed and stops at zero position. Then next scan in another (or same) direction begins. Shown in Fig-5 is the timing chart of a step jump to data read cycle.

By pressing button on front panel of the function setting module, the scanner could be switched to one of the four different running modes: X auto, Y auto, X-Y auto and single step manual control. Normally X-Y auto mode will be selected. In that case, the X and Y scan will automatically alternate repeatedely. The micro-computer will keep doing on line analising while taking data in, and then display profile curve on screen. What should mentioned is that the X and Y axis sweep must be cosine scale instead of linear scale[2].

Not only profile information, one can also know about the beam intensity by summing the 120 datum. Since we have:

$$Jx = \sum_{K=0}^{N} \bar{q}_{xK} + E_x$$

$$Jy = \sum_{K=0}^{N} \bar{q}_{yK} + E_y$$

and

$$Jx = Jy = k \cdot J$$

where J is the beam intensity while Jx,Ex and Jy,Ey are beam intensity measured and error correction term in X and Y respectively. The Ex,Ey and k can be found with experiment absolute correction and Jx = Jy boundary condition. So we can get J calculated.

For the scanner, pofile resolution is expected being better than 1.5 mm when 1 mm probes are used. The probes are not pre-shaped because intermittent step jump will not create effective bending[3]. The resolution is mainly limited by probe diameter, probe vibration when arm rotates, etc.

Status

With our present developed AP system, the parameter measurement and data collection on running cyclotron in INST. become fairly easy and comparatively effective. It has been successfully used in measuring total beam time-intensity integration when producing isotope At^{211}. and continuously monitoring beam on time axis in the experiment of calibration d-Be neutron irradiation field and so on. The system helps operator in knowing about the present cyclotron parameters and preset conditions for experiments, facilitates the cyclotron running and experiment records keeping.

Profile scanner is scheduled to have its first beam test in next november. What have already being built are all electronics modules and head assembly. The results of bench test and final system simulation experiment are promising.

Expanding the system in future to the ON/OFF sequential control and setpoint adjustment are considered.

Reference

* Research program supported by the Ministry of National Education

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