HIGH CURRENT BEAM PROFILE MONITOR (WIRE SCANNER)

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Abstract

An inexpensive, high current, rotating wire monitor was developed for the CP42 cyclotron at TRIUMF. The monitor, housed in a 45° diagnostic box, can produce horizontal and vertical beam profiles at beam currents up to 200 µA. Data can be displayed on storage or a high persistance oscillosocope or, in conjunction with the developed software, by a low cost personal computer (Commodore 64). The program can produce an approximation of beam cross section and other graphics. Scanner construction and the computer displays are presented in this paper.

Introduction

A 42 MeV isotope production cyclotron (CP42) is installed and operating at TRIUMF. Two fixed energy and one variable (11-42 MeV) energy beam lines were initially provided. With the installation of a switching magnet and nine additional beam lines, the need for a more versatile and accurate diagnostic system became apparent. In its final version the system consists of a beam spot scintillating monitor, CCTV and optical system and wire scanner for each beam line. The monitors are housed in a special, multi-purpose 45° diagnostic box.

The objective was to create a simple, low cost system that would allow real time, low current tuning using a scintillating beam spot monitor and beam profile display at full currents up to 200 µA. Initially a storage oscilloscope was used to display the beam profile, however, a personal computer proved to be more cost effective and versatile.

Monitor Description

Design Considerations

After initial tests with a pendulum type two wire monitor it became apparent that a simpler and less expensive alternative would be a rotating wire scanner. The aim was to design a compact, simple monitor that could provide beam shape and position information at full beam currents with ±1 mm resolution. Tungsten wire rotating at 300 rpm was used to achieve this. Since "Dependex" vacuum fittings were already used on the beam lines it was decided to standardize all diagnostic equipment around the 2" fitting. Monitor and diagnostic box size was limited by existing available space in some beam lines and restricted to under 220 mm long. Expected beam size was up to 50 mm diameter.

Diagnostic Box

Figure 1 shows the diagnostic box and monitors. A four-sided welded aluminum box is provided with four 2" "Dependex" openings for viewing and future use. One beam line opening is provided on two opposite sides. Two covers, with one opening each, support the monitors. The box, mounted at 45°, serves also as beam line vacuum valve adaptor and pumping port.
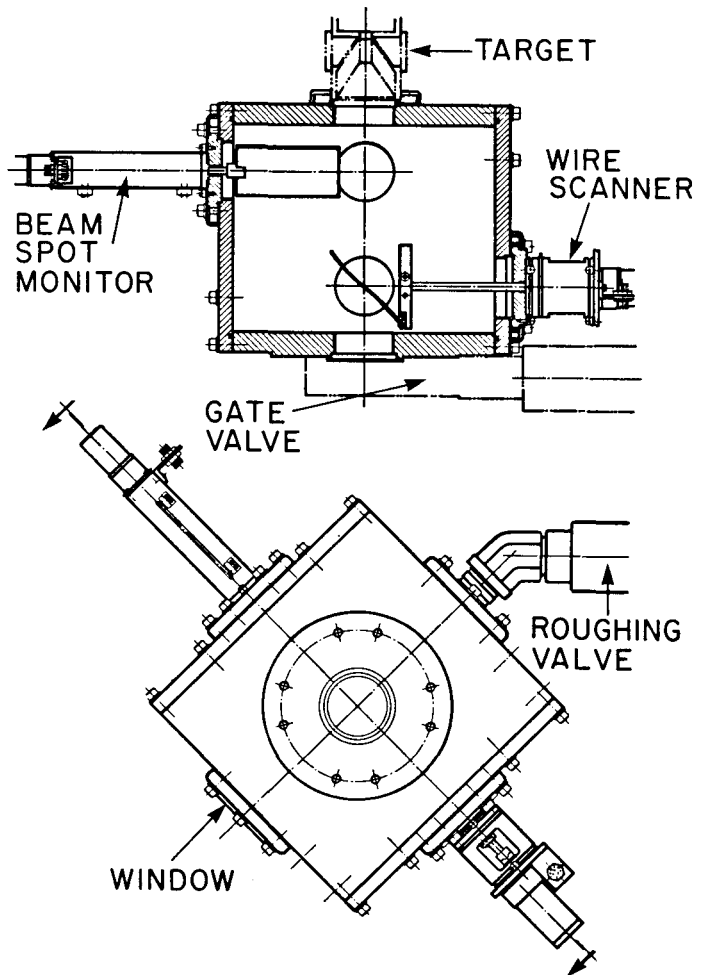

Fig. 1

Scanner Construction

A cross section and view of the scanner are shown in Fig. 2. Tungsten wire, 0.5 mm thick, is bent around a 60 mm diameter former and clamped in an aluminum arm attached to a stainless steel shaft. A "Vespel" disc, machined to form a 2" "Dependex" fitting on one side, retains the two O-rings that form a rotary vacuum feedthrough. On its opposite side a position potentiometer is mounted. It is a continuous rotation servo-mount control potentiometer, its original shaft replaced with a 150 mm long, ground stainless steel rod. The existing two ball bearings in the potentiometer are used to support the shaft. It is fitted with an odlaham type coupling at the other end. A 300 rpm D.C. gearhead motor drives it directly. A limit switch is provided to execute one scan (one full turn) and to ensure the parked wire position is outside the beam path.

In operation a switch is momentarily closed to start the scan. Position information is received from the potentiometer and plotted against beam current picked up by the wire. The resulting plot shows horizontal and vertical beam size and position. Plots can be recorded directly on an X-Y recorder, storage oscilloscope or, with the described interface and software, by a P.C. With the data in a computer, it can be transformed and displayed in ways that are easier to interpret than the standard X-Y plot. We can make a permanent hardcopy of the data using a low cost 4-colour plotter.

Computer Operation

Hardware Description

We chose the Commodore 64 computer due to its low cost, flexibility and our familiarity with its architecture and operation.

Figure 3 shows the interfere circuit. An RF filter is installed on the current input to eliminate high frequency noise. We found that the signal could be increased by hooking up a 45 volt battery in series with the scan wire. This negative bias tends to increase the secondary emission. The battery life should equal its shelf life.

The hardware is built into a standard 19" × 5 1/4" rack mount chassis. The chassis holds the C-64 main circuit board, the C-64 power transformer and a circuit board rack which holds the A/D board. There are several extra slots in the rack to accommodate future buffer cards for the remaining A/D input channels. The front panel of the rack includes 3 buttons: "SELECT", "EXECUTE", and "SCAN".
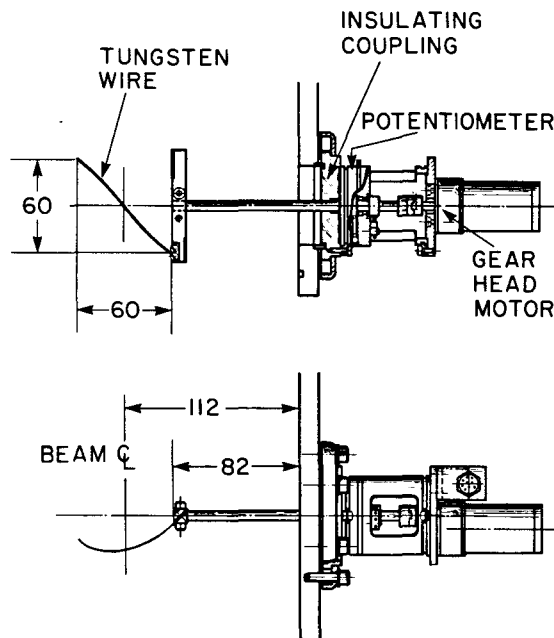

Fig. 2.

Operation

During one full rotation the wire will cross the beam path twice at right angles. When the monitor is placed at 45° the scan will produce a horizontal and vertical beam section.[1] The beam current is picked up directly from the insulated body of the monitor.
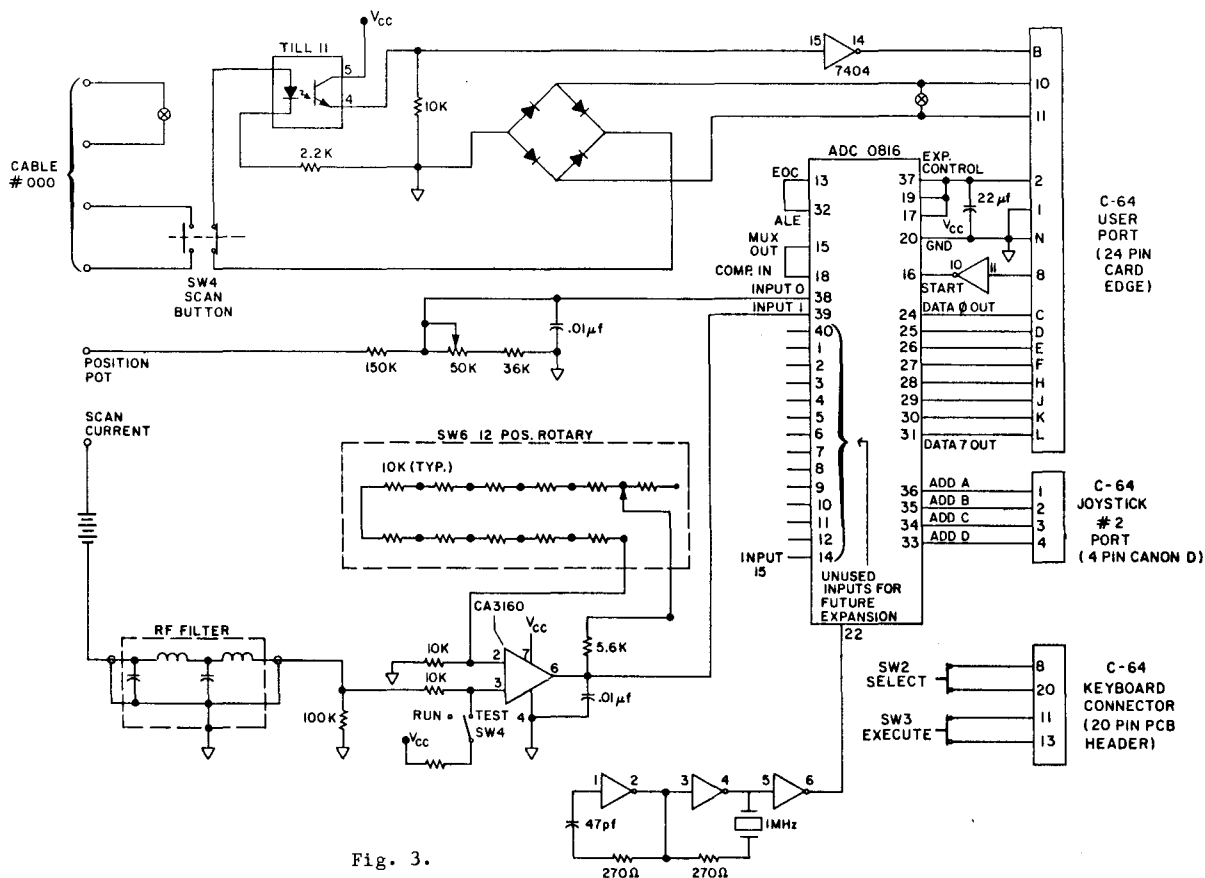

Fig. 3.

Software Description

The WIRESCAN program consists of three parts:

1. A machine language graphics utility.[2]
2. A machine language data collection subroutine.
3. The main BASIC program.[3]

After the BASIC program was written and debugged we compiled it to improve the execution speed. There is a short BOOT routine that loads the above modules and sets the C-64 to the proper configuration.

The machine language data collection subroutine is the heart of the program. This routine is quite straightforward. After entry to the routine all of the C-64's interrupts are turned off and the program idles until the scan button is pushed. Then a hardware timer built into one of the C-64's 6526 CIA chips is started. This timer determines the length of the data collection interval. After the timer counts down the routine moves the data to a second buffer, clears the input buffer to zero and restores the C-64 interrupts. Control is transferred to the BASIC program and the data is plotted in a standard X-Y plot (Fig. 4).

In order to display the data in a more intuitive manner, a pseudo cross-sectional plot routine is included. The routine takes the ratio of an individual vertical sample to the sum of all vertical samples and then multiplies it by a similar horizontal ratio. The magnitude of the result is used to determine the colour (one of 3 possible colours) of that particular X-Y coordinate in the plot. If a sample's value is zero the routine skips the calculations. This speeds things up considerably. The program performs the same calculations when doing a hard copy. It is important for the user to realise that this plot is only pseudo cross-sectional, however, it provides a useful graphic interpretation of the beam shape (Fig. 5).

A three dimensional plot routine is included. This allows one to view the cross-sectional intensity of the beam with greater resolution than the 3 colours possible with the cross-sectional plot. Thirty-two levels of intensity are displayed. The same calculations are used, as in the cross-sectional plot, to obtain the intensity data. There is no provision to make a hard copy of this plot (Fig. 6).
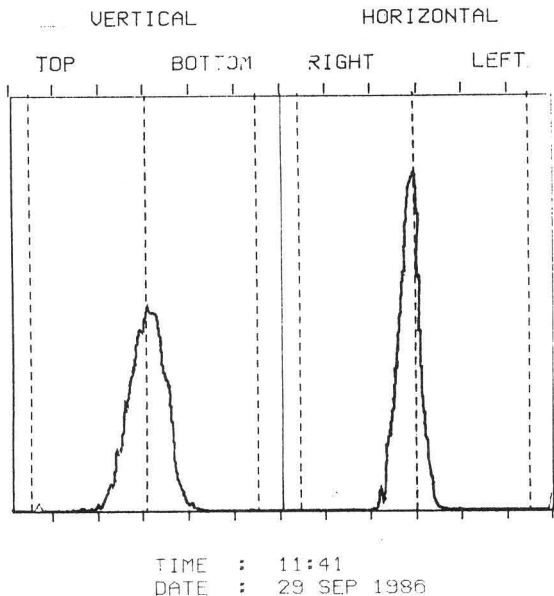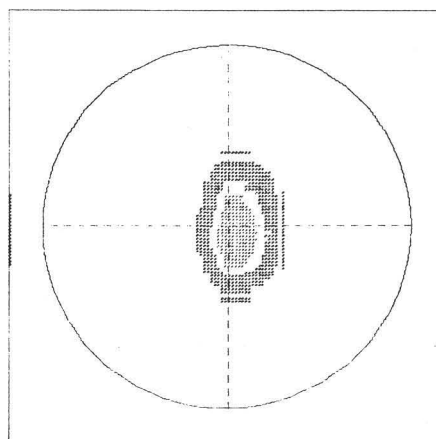
(BEAM DIRECTION: INTO PAPER)
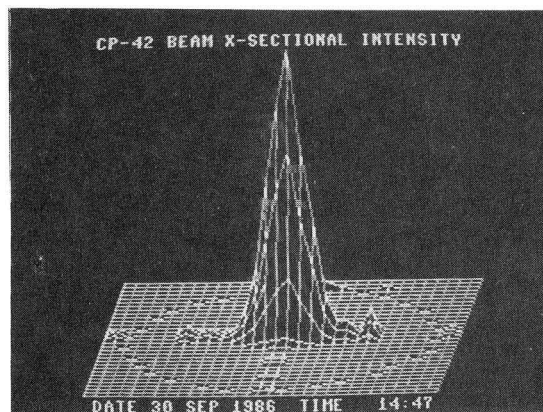

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Fig. 5.

Fig. 6.

The program uses the time-of-day clock in one of the C-64's 6526 CIA chips to keep track of the time and data. When a hardcopy of the plot is made the time and date of the scan are included.

Conclusion

Seven monitors are in operation and a modified larger version was constructed for other applications at TRIUMF. They provide a cost effective alternative to more sophisticated devices without sacrificing accuracy or versatility. Future improvements include putting the program on ROM, increasing plot resolution and writing routines to automatically select different ranges.

References

1. G. Hortig, "A Beam Scanner for Two Dimensional Scanning with One Rotating Wire", Nuclear Instruments and Methods 30, 355 (1964).
2. G. Kiziak, "Transactor" Vol. 5, #6.
3. P. Bloemhard, TRIUMF Design Note TRI-DN-86-16, 1986.
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Fig. 4.