

BEAM PROFILE MONITORING SYSTEM WITH AN OPTICAL FIBER ARRAY  
IN TRISTAN MAIN RING

Mitsuo AKEMOTO and Atsushi OGATA  
National Laboratory for High Energy Physics  
Oho-machi, Tsukuba-gun, Ibaraki-ken 305, Japan

ABSTRACT

A beam profile monitoring system with an optical fiber array has been developed. The array is one-dimensional and transmits light pulses to a photomultiplier tube (PM). The signal from the PM is sampled by a waveform digitizer at a rate of 100 MHz. The digitized data are transmitted to a personal computer via GPIB and processed. The result is displayed on a color CRT. With this system, we have measured the beam profiles of successive revolutions after the injection in the TRISTAN Main Ring (MR).

INTRODUCTION

Monitoring of the beam profile is important for operation and study of an accelerator. For studying a transient behavior of the beam in a case where beam oscillations are very rapidly damped, about 100  $\mu$ sec for example, a fast profile monitor is necessary. In an electron storage ring, an optical fiber array<sup>1)</sup> which detects the synchrotron radiation is one of tools enabling fast observation of the beam profile. The monitor described here consists of 10 optical fibers with lengths ranging from 2 m to 20 m at 2 m step, corresponding to delay times from 10 ns to 100 ns at 10 ns step. Each fiber has dimensions of the 400  $\mu$ m core radius and the 550  $\mu$ m fiber radius. The input end forms a 4.95 mm long one-dimensional array to accept the incident light (synchrotron radiation) and the output end is bundled and connected to a PM. The spatially distributed synchrotron light at the fiber input becomes a sequence of light pulses at the PM. The output signal of the PM is sampled by a transient digitizer and read into a computer. It is thus possible to observe the instantaneous beam profile as long as the time interval of signals is 100 ns at least. We have developed a monitoring system of this kind to observe the change of the beam profile during successive revolutions just after the beam is injected in the MR.

SYSTEM DESCRIPTION

Hardware

The block diagram of the system is shown in Fig. 1. It consists of the optical fiber array, waveform digitizer, sampling clock generator and personal computer NEC PC-9801E. The synchrotron light<sup>2)</sup> is reflected by a beryllium mirror in the vacuum chamber and only the visible component is taken out into the air. The visible light is then reflected upward by a system of remote-controlled mirrors. It reaches an optical bench in an experimental room right above the accelerator tunnel. The optical path length is about 25 m from the light source. At the bench, an optical lens (SMC Pentax  $f = 1000$  mm) focuses the light and then another  $f = 100$  mm lens magnifies it so that a unit magnification is obtained at the input end of fibers. The bench has also mirror arrangements which enable observation of both the  $e^+$  and  $e^-$  beam profiles. Though the optical fibers are arrayed linearly, both the horizontal and vertical profiles can be monitored by use of a Dove prism.<sup>3)</sup>

The output light from the fibers is detected by a HAMAMATSU H1941 photomultiplier tube, the rise time of which is about 1.3 ns for a dc supplied voltage of 2.5 KV. Pulse signals from the PM are digitized by a 10 bit waveform digitizer (SONY/TEKTRONIX RTD-710). It has an input-frequency range of DC to 100 MHz which is enough for sampling the pulse signals of the PM. The sampling clock signal for the digitizer is generated by a triggering pulse called "beam-trigger" which is synchronized with the beam revolution frequency 99.33 KHz for MR. The sampling clock makes 10 equally spaced pulses for the digitizer for each beam trigger. The time chart is shown in Fig. 2. Since the memory size of the digitizer is of 64 k words, the maximum record time for one bunch is 6.4 msec in the MR. It is sufficient time to catch the whole behavior of the beam because of the radiation damping of a few msec.

The digitized data by the RTD-710 are transferred to the personal computer through the GPIB and processed. The result is displayed on a color CRT.

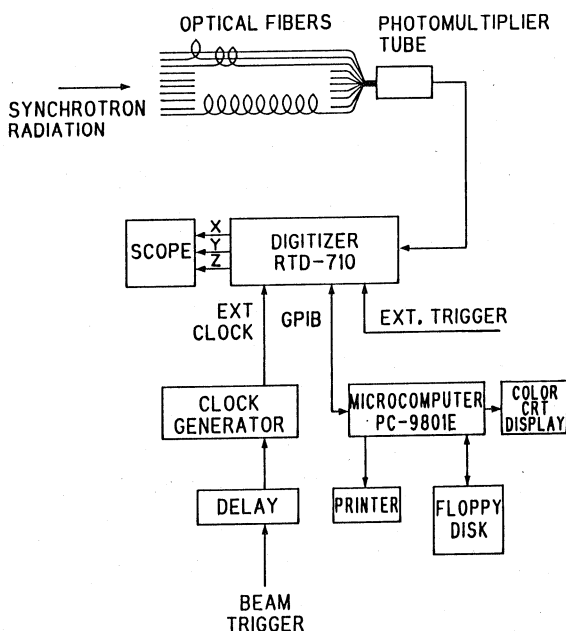


Fig. 1 Block diagram of the beam profile monitoring system with an optical fiber array.

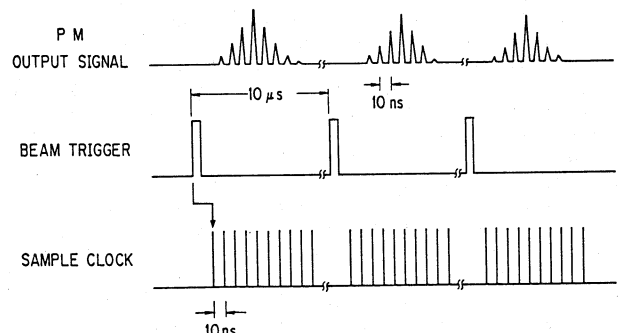


Fig. 2 Time chart of the waveform digitizer. Pulse signals from the PM are digitized at rate of 100 MHz.

Software

The flow chart of the program is shown in Fig. 3. The program is written in BASIC. The program consists of the following four groups:

- (1) Parameter set for the digitizer: Number of sampling data, trigger mode and input gain are set.

- (2) Data transfer :  
After number of data points and start point are input, the raw data taken by the digitizer are transferred to PC-9801E.
- (3) Data processing and display :  
The raw data are rearranged for each fiber channel. The calculation by a Fast Fourier transform ( FFT ) is performed. After this data processing, a mountain view profile and FFT data are displayed on a CRT.
- (4) Data saving :  
The rearranged data and FFT data which are stored in the buffer memory of PC-9801E are saved on a floppy disk.

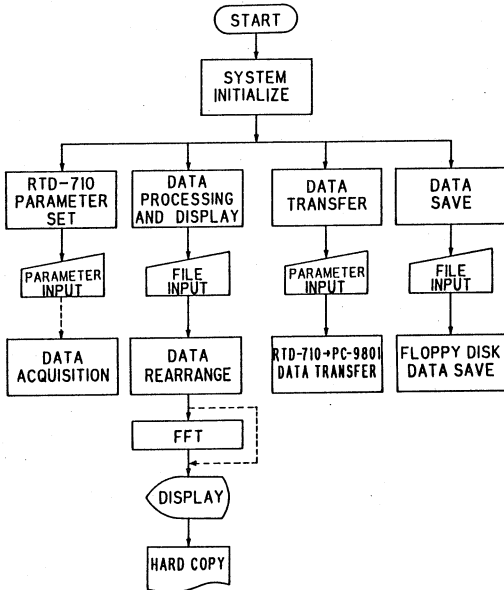


Fig. 3 Flow chart of the program. Each routine can be independently performed by menu commands.

### SYSTEM OPERATION

Before the beam profile measurement, the system is initially adjusted by following steps. First, the image of the synchrotron radiation from the MR is focused on the input of fibers by adjusting the optical system. Next, the delay time between the sampling clock and the beam trigger is adjusted so that the digitizer samples the PM signals at an optimum timing. Finally, the input gain of the digitizer and the dc voltage for the PM are adjusted so that a beam profile can be measured with a sufficient resolution.

Fig. 4 shows the trace of a PM output signal. Peaks of the trace correspond to the signal from each optical fiber. The PM output is digitized by the RTD-710 as shown in Fig. 5. In order to observe the transient behavior of the beam profile just after the injection, the digitizer is triggered by the MR injection kicker timing pulse. Fig. 6 shows an example of the mountain view display of the horizontal profile at the injection at 7.3 GeV. Each trace is a beam profile separated by 10  $\mu$ sec ( one revolution ) from the neighboring profile. The bunch oscillation is due to the excursion at the injection. The signals of each channel as a function of time after the injection are also shown in Fig. 7. From this display, it is found that the damping time is about 1.3 msec (  $\sim 130$  turns  $\times$  10  $\mu$ sec ). Furthermore, the data are analyzed by the FFT for each channel. The FFT display is shown in Fig. 8. A prominent peak at 31 KHZ corresponds to the horizontal betatron oscillation. This value is in good agreement with the value obtained by a tune measurement system. <sup>2)</sup>

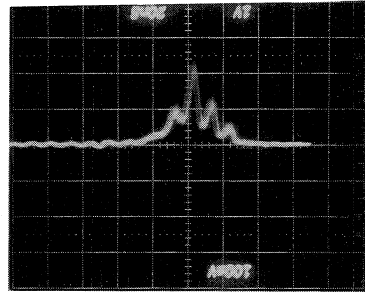


Fig. 4 Trace of a PM output signal. 20 nsec/division.

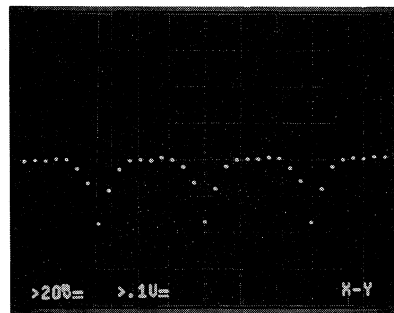


Fig. 5 Beam profiles digitized by the RTD-710. 10 nsec sampling.

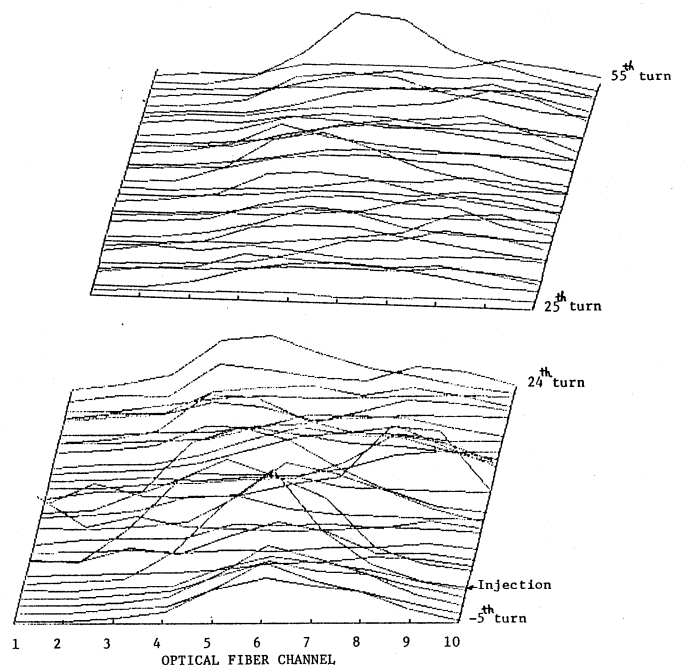


Fig. 6 Horizontal mountain view display at the injection. 10  $\mu$ sec /step.

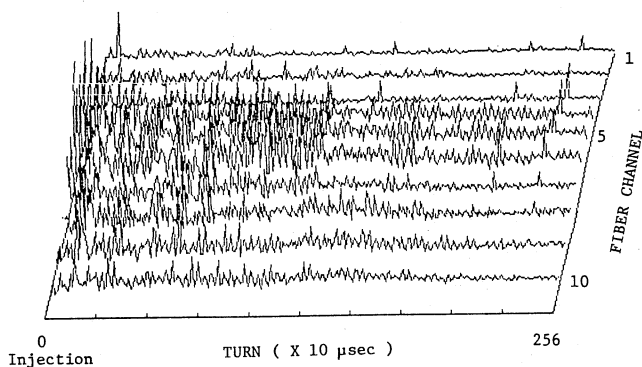


Fig. 7 Signals of each channel as a function of time after the injection.

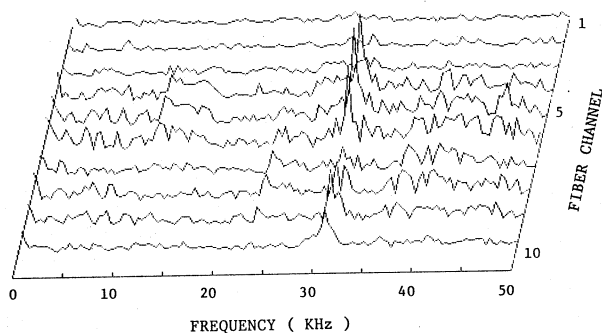


Fig. 8 FFT of the signals of each channel after the injection.

#### CONCLUSION

This system has enabled us to observe the behavior of the beam profile of each revolution just after the injection. The horizontal betatron oscillation frequency is also measured exactly by this method. This system is useful in studying the profile of the synchrotron radiation of an electron storage ring. A two-dimensional beam profile can be easily obtained by adding more fiber arrays.

One of main problems in this system is a rather slow transfer rate between PC-9801E and RTD-710 and long FFT calculation time. If these programs are rewritten in a machine code, the response time will become shorter than now. An improved monitor system will be useful tool for beam diagnosis.

#### ACKNOWLEDGEMENTS

The authors express their appreciation to Professors K. Takata, K. Uchino and Y. Yamazaki for their encouragements and valuable advices.

#### REFERENCES

- 1) A. Ogata, "Space-to-Time Conversion of Optical Signal Using Fiber Delay and Its Application to Accelerator Beam Profile Monitor", Japan. J. Appl. Phys. 23(1984)L716.
- 2) T. Ieiri et al., "Beam Monitors and Transverse Feedback System of TRISTAN Main Ring", KEK Preprint 87-21.
- 3) Walter G. Driscoll, "Handbook of optics", MCGRAW-HILL BOOK COMPANY(1978).